SPATIAL MODELLING OF GASTROENTERITIS PREVALENCE FOLLOWING THE FEBRUARY 22, 2011 EARTHQUAKE

AND

IDENTIFICATION OF SUCCESSFUL FACTORS PREVENTING OUTBREAKS AT EMERGENCY CENTRES

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For My Husband

Shan

And

My parents; and grandparents

I couldn’t have made this far without all your support!

THESIS ABSTRACT

The potential for a gastroenteritis outbreak in a post-earthquake environment may increase because of compromised infrastructure services, contaminated liquefaction (lateral spreading and surface ejecta), and the presence of gastroenteritis agents in the drinking water network. A population in a post-earthquake environment might be seriously affected by gastroenteritis because it has a short incubation period (about 10 hours).

The aim of this multidisciplinary research was to retrospectively analyse the gastroenteritis prevalence following the February 22, 2011 earthquake in Christchurch. The first focus was to assess whether earthquake-induced infrastructure damage, liquefaction, and gastroenteritis agents spatially explained the recorded gastroenteritis cases over the period of 35 days following the February 22, 2011 earthquake in Christchurch. The gastroenteritis agents considered in this study were Escherichia *coli* found in the drinking water supply (MPN/100mL) and Non-Compliant Free Associated Chlorine (FAC-NC) (less than <0.02mg/L). The second focus was the protocols that averted a gastroenteritis outbreak at three Emergency Centres (ECs): Burnside High School Emergency Centre (BEC); Cowles Stadium Emergency Centre (CEC); and Linwood High School Emergency Centre (LEC).

Using a mixed-method approach, gastroenteritis point prevalence and the considered factors were quantitatively analysed. A damage profile was created by amalgamating different types of damage for the considered factors for each Census Area Unit (CAU) in Christchurch. The damage profile enabled the application of a variety of statistical methods which included Moran's *I* , Hot Spot (HS) analysis, Spearman's Rho, and Besag–York–Mollié Model using a range of software. The qualitative analysis involved interviewing 30 EC staff members. The data was evaluated by adopting the Grounded Theory (GT) approach.

Spatial analysis of considered factors showed that highly damaged CAUs were statistically clustered as demonstrated by Moran's *I* statistic and hot spot analysis. Further modelling showed that gastroenteritis point prevalence clustering could not be fully explained by infrastructure damage alone, and other factors influenced the recorded gastroenteritis point prevalence. However, the results of this research suggest that there was a tenuous, indirect relationship between recorded gastroenteritis point prevalence and the considered factors: earthquake-induced infrastructure damage, liquefaction and FAC-NC.

Two ECs were opened as part of the post-earthquake response in areas with severe infrastructure damage and liquefaction (BEC and CEC). The third EC (CEC) provided important lessons that were learnt from the previous September 4, 2010 earthquake, and implemented after the February 22, 2011 earthquake. The ECs were selected to represent the Christchurch area, and were situated where potential for gastroenteritis was high. BEC represented the western side of Christchurch; whilst, CEC and LEC represented the eastern side, where the potential for gastroenteritis was high according to the outputs of the quantitative spatial modelling. Qualitative analysis from the interviews at the ECs revealed that evacuees were arriving at the ECs with gastroenteritis-like symptoms. Participants believed that those symptoms did not originate at the ECs. Two types of interwoven themes identified: direct and indirect. The direct themes were preventive protocols that included prolific use of hand sanitisers; surveillance; and the services offered. Indirect themes included the EC layout, type of EC building (school or a sports stadium), and EC staff. Indirect themes governed the quality and sustainability of the direct themes implemented, which in turn averted gastroenteritis outbreaks at the ECs. The main limitations of the research were Modifiable Areal Units (MAUP), data detection, and memory loss.

It was concluded that gastroenteritis point prevalence following the February 22, 2011 earthquake could not be solely explained by earthquake-induced infrastructure damage, liquefaction, and gastroenteritis causative agents alone. However, this research provides a practical method that can be adapted to assess gastroenteritis risk in a post-earthquake environment. Creating a damage profile for each CAU and using spatial data analysis can isolate vulnerable areas, and qualitative data analysis provides localised information. Thus, this mixed method approach can be used in other disaster contexts to study gastroenteritis prevalence, and can serve as an appendage to the existing framework for assessing infectious diseases. Furthermore, the lessons learnt from qualitative analysis can inform the current infectious disease management plans, designed for a post-disaster response in New Zealand and internationally.

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AT	Axial Table
BEC	Burnside High School Emergency Centre
BYM Model	Besag–York–Mollié Model
CAR	Conditional Autoregressive Model
CAU	Census Area Unit (otherwise known as Aerial Unit)
CEC	Cowles Stadium Emergency Centre
CD	Civil Defence
CDEM	Civil Defence and Emergency Management
CCC	Christchurch City Council
CG	Coastguard (Canterbury)
CI	Credible Interval (95%) (WinBUGS14 Modelling)
CIMS	Coordinated Incident Management System
CDHB	Canterbury District Health Board
DIC	Deviance Information Criterion (WinBUGS14 Modelling)
CDEM	Civil Defence Emergency Management
E	Spatial Residual per CAU (WinBUGS14 Modelling)
EC	Emergency Centre
Ec	E.*coli* count per CAU (WinBUGS14 Modelling)
ECM	WinBUGS14 Model Name (Model 2) for Expected Cases of E.*coli* Using the Population of the Study Area as the Maximum Number of People that can be Exposed to E.*Coli* per CAU
EE	Estimated Effect (WinBUGS14 Modelling)
ESR	Institute of Environmental Science Research Limited in New Zealand
FAC	Free Associated Chlorine (compliant >0.02mg/L) (WinBUGS14 Modelling)

FAC-NC	Free Associated Chlorine Non-Compliant (<0.02mg/L) (WinBUGS14 Modelling)
GAST	WinBUGS14 Model Name (Model 1) for Expected Cases of Gastroenteritis Point Prevalence Using the Population of the Study Area as the Maximum Number of People that can have Gastroenteritis per CAU
GLM	General Linear Model (WinBUGS14 Modelling)
GP	General Practitioner
HEC	Human Ethics Committee
HS	Hot Spot
ID	Infectious Disease
LEC	Linwood High School Emergency Centre
LIQ	Percentage of Liquefied Area per CAU (WinBUGS14 Modelling)
MCDEM	Ministry of Civil Defence and Emergency Management
MOH	Ministry of Health
NC	No Change
NZ	New Zealand
NZWWA	New Zealand Water and Waste Association
PL	Portable Lavatory
WHO	World Health Organisation
WSB	Water Supply Submain Pipe Damage Count per CAU
WSM	Water Supply Main Pipe Damage Count per CAU
WW	Wastewater Pipe Damage Count per CAU

CHAPTER 1: INTRODUCTION

1.1 RESEARCH CONTEXT AND OBJECTIVES

Earthquakes are a type of natural disaster that can give rise to extensive damage, and has the potential to cause large-scale impacts to society. An example of an impact is Gastroenteritis, an infectious disease commonly known as "stomach bug" or "intestinal flu" is an infectious disease that may occur in the aftermath of an earthquake. Occurrence of gastroenteritis outbreaks following an earthquake have been reported in the past (Ghorbani, Jafari, & Talebi, 2005). Earthquake-induced infrastructure damage, such as water network damage, may act as a possible exposure path for infectious diseases like gastroenteritis (Bartels & VanRooyen, 2012; Kouadio, Aljunid, Kamigaki, Hammad, & Oshitani, 2012). Damage to the water network may contaminate the water supply and become a pathogen source. Escherichia *coli* is the indicative pathogen used to identify water contamination, and Free Associated Chlorine (FAC) is used to eliminate E.*coli* (Ministry of Health [MOH], 2008). In this study, it was considered if FAC was non-compliant (<0.02mg/L) then it was considered as a gastroenteritis agent, because if the water was contaminated and the chlorine concentration was not high enough then non-compliant FAC may act as a gastroenteritis agent (Gupta et al., 2007). If this contaminated water is consumed, it may give rise to an infectious disease (Laine et al., 2011). E.*coli* has been associated with gastroenteritis outbreaks in the past (Swerdlow et al., 1992).

The effects of gastroenteritis incidences (mostly diarrhoea or vomiting) after a disaster tend to be disruptive to society rather than destructive. In spite of this, gastroenteritis can be highly contagious in a post-earthquake setting, especially where people congregate. One example of where people congregate, and gastroenteritis is likely to occur is at an Emergency Centre (EC), set up by authorities as part of a post-earthquake emergency response.

An EC serves as part of the short-term disaster emergency response to provide essential provisions for people affected by the disaster. This poses the possibility of gastroenteritis prevalence at an EC, because of the surrounding infrastructure damage, and the potential for people arriving at the EC having been exposed to other pathogen sources. Studies on

ECs after a disaster have been documented but not copiously. Nor are they widely reported from a preventive perspective.

Hence, this interdisciplinary research expands on the present knowledge of gastroenteritis prevalence after an earthquake from a disaster management perspective in two ways. First, it assess whether the recorded gastroenteritis cases were spatially clustered in order to determine whether those clusters were associated with the following factors: earthquake-induced infrastructure damage; liquefaction ground damage (lateral spread and surface ejecta); gastroenteritis agents—Non-Compliant Free Associated Chlorine (FAC-NC) and E.*coli.*

The second aim of this research is to analyse preventive protocols implemented that aided in preventing gastroenteritis outbreaks at the ECs after the February 22, 2011 earthquake. Understanding those two aims can provide useful protocols that may have been refined or created because of the unique situation as a consequence of the February 22, 2011 earthquake. Thus, this research aims may provide new insights into the intractable relationship between contaminated drinking water supply, and gastroenteritis prevalence with respect to an earthquake's damage profile. Meanwhile, the mitigative approaches identified can help to improve the existing epidemic management plans. Collectively investigating a possible infectious disease following an earthquake is enhanced by using a multidisciplinary approach.

1.2 RESEARCH QUESTIONS

The research questions for this thesis are based on the context of the February 22, 2011 earthquake at Christchurch, New Zealand. Because the study utilises the contextual events of real-life phenomenon—the February 22, 2011 earthquake—by definition, this study becomes a case study (Yin, 2008). Two successive parts form the research questions as outlined below:

Quantitative analysis: Investigate whether earthquake-induced infrastructure damage (such as water and wastewater networks), liquefaction ground damage (lateral spread and surface ejecta), and gastroenteritis agents (E.*coli* and Free Associated Chlorine-FAC) spatially explained the recorded gastroenteritis cases after the February 22, 2011 earthquake in Christchurch.

Qualitative analysis: Identify the preventive protocols implemented to avert gastroenteritis outbreaks at the ECs that were open to the public following the February 22, 2011 earthquake.

1.3 CHRISTCHURCH EARTQHUAKE: FEBRUARY 22, 2011 EARTHQUAKE

The Christchurch metropolitan area, located in the South Island of New Zealand, covers 417 km^2 of the Canterbury Plains (Brown, Weeber, & Reay, 1992). The city is located on Holocene deposits, and originally the site of swaps with poorly consolidated alluvial soil before developing into a service centre for agriculture and horticulture (Brown et al., 1992). Because of soil composition and high ground water level across the city, Christchurch city is susceptible to liquefaction ground damage, which means that under stress, the soil behaves like a "semi-liquid" due to loss of soil cohesion and stiffness from applied stress (Brackely, 2012). For example, there was newspaper report of liquefaction ground damage observed in Belfast after the Cheviot earthquake in 1901 (Berrill, Mulqueen, Ooi, & Pautre, 1994). The liquefaction ground damage susceptibility in Christchurch has been extensively studied and produced many hazard maps prior to the 2010-2011 earthquakes in Christchurch (Brackely, 2012). Christchurch is located in the more tectonically active part of New Zealand, so is prone to earthquakes (Brown et al., 1992). Historical earthquakes closer to Christchurch have been recorded in the past even as far back as 1869 (Berrill et al., 1994). However, the September 4, 2010 earthquake that took place in broke the region's 23-year earthquake-free streak. (Quigley et al., 2010). Christchurch city is the second largest city in New Zealand (Statistics New Zealand, 2013). In 2013 census, Christchurch city had a population of 341,469: a 2% decline since 2006 census (Statistics New Zealand, 2013).

The Christchurch city is the study area for this research, which is illustrated in Appendix A, and the February 22, 2011 earthquake serves as the event, which frames the case study for this research.

On September 4, 2010 there was a 7.1 magnitude earthquake (otherwise known as Darfield earthquake) with no loss of life (Quigley et al., 2010). Then, a subsequent 6.3 magnitude earthquake struck Christchurch on February 22, 2011 at 12.51pm (GeoNet, 2013). Because of the time of day, the earthquake resulted in 181 fatalities along with extensive infrastructure and liquefaction ground damage (GeoNet, 2013).

1.3.1 LIQUEFACTION GROUND DAMAGE

The Canterbury earthquakes, and especially the February 22, 2011 earthquake, caused unprecedented large-scale liquefaction ground damage in Christchurch, which was collectively characterised by surface fissures, sand boils, ground depressions and resettlement; and sand/silt ejecta with muddy water that disseminated on the ground surface (Cubrinovski et al., 2011). This induced large-scale damage to structures, including commercial buildings, residential houses, bridges, and infrastructure networks. In fact, about 6000 homes were deemed abandoned and another 15,000 homes sustained range of liquefaction ground damage (Cubrinovski, Henderson, & Bradley, 2012). Furthermore, given favourable wind conditions or vehicular disturbance, dried liquefied silt may pose health hazards if it becomes airborne and inhaled (Institute of Environmental Science and Research [ESR], 2012c).

1.3.2 WATER NETWORK DAMAGE

Christchurch's water supply is sourced from deep aquifers (which are pumped into portable tanks on the hills), and wells across the city pumped into a reticulating pipe network (Christchurch City Council [CCC], 2012). The network is composed of 1600km of main pipes and 200km of submain pipes (Christchurch City Council [CCC], 2012). The water network suffered major damage due to pipe cracks and ground settlement, instigating chlorination of water (Ministry of Health [MOH], 2012). As a consequence, water testing samples showed E.*coli* count to be above the basal level, and chlorination was implemented along with public health notices to boil water (MOH, 2012).

Fifty-five temporary water supply sites were established with stationary water tanks, immediately following the earthquake (Gordon, 2011). However, Civil Defence Emergency Management (CDEM) media released on February 23, 2011 that an estimated that up to 80% of the city had no drinking water supply that day (CCC, 2011).This meant that over 300,000 people had no access to reticulated water services for up to the day after the earthquake (MOH, 2012). By February 26, 2011, about 50% of the city still had no access to water (Reid P., Brunsdon, Paul, & Oughton, 2004).

1.3.3 WASTEWATER NETWORK DAMAGE

Likewise, the wastewater network was so damaged that by March 4, 2011, only 25% of the normal flow was received at the Bromley treatment plant (Gordon, 2011). A temporary sewerage system composed of chemical and portable lavatories was established, where sewerage services were unavailable (Potangaroa, 2011). Furthermore, silt and sand that was arriving at the plant caused the sludge removal system to fail at the Bromley treatment plant (Gordon, 2011). All sewerage was discharged to streams and rivers immediately following the February 22, 2011 earthquake, but by April 2011, 67% of the normal flow of sewerage was arriving at the treatment plant (Gordon, 2011). There were prompt power outages in the immediate aftermath of the earthquake (Gordon, 2011). Both of the 66kV cables were inoperable which supply electricity to urban areas (Eidinger, 2011).

Under the CDEM Act 2002 (which promote; co-ordinate; provide local; and national emergency response in NZ) a regional emergency was declared at 1445 hours on the day of the February 22, 2011 earthquake, followed by the declaration of a state of national emergency on February 23, 2011, at 1030 hours (McLean I., 2012). As a result, additional resources such as chemical lavatories for residents and emergency personnel were mobilised nationally, and internationally (McLean I., 2012). Even though New Zealand has experienced natural disasters in the past, the February 22, 2011 earthquake was the first occasion in which a national emergency has been declared (McLean I., 2012). The state of emergency was repeatedly extended for 10 weeks until April 30, 2011 (McLean I., 2012; NZPA, 2011).

The earthquake caused widespread damage to the water network, wastewater networks, and caused severe liquefaction ground damage throughout many parts of Christchurch (Giovinazzi et al., 2011). Even after such damage, there were no reported gastroenteritis outbreaks for weeks following the earthquake (Dell, 2012). Yet, some cases of gastroenteritis were being reported at ECs (Dell, 2012). Indeed, for these reasons, Christchurch following the February 22, 2011 earthquake is a candidate for a case study. Furthermore, this research enables the recording of specific details pertaining to ECs that may help to deepen the current understanding of gastroenteritis management in a post-disaster context. Thus, fostering lessons learnt for the future.

1.4 RESEARCH STRUCTURE

This research explores the spatial association amongst the recorded gastroenteritis cases and their associated factors as well as successful protocols implemented at ECs that prevented a gastroenteritis outbreak. Table 1-1 provides a brief synopsis of the contents of each chapter. Abbreviations used in this research are provided at the beginning of this research. Each chapter includes objectives and succinct chapter summary where required.

Table 1-1: Research chapter outline

CHAPTER NUMBER	TITTLE	CHAPTER PURPOSES
1	Introduction	Outlines the research context for the research, the study area, and provides research road map.
2	Literature Review	The literature review begins with core definitions; and describes the issues surrounding infectious diseases and natural disasters (and especially earthquakes), in particular earthquakes. This is followed by an outline of the vital factors that influence gastroenteritis after a natural disaster and New Zealand's relevance to gastroenteritis and Emergency Centres. The chapter continues with a discussion of selected Emergency Centres established after the disaster, and identifies a number of research gaps in the literature. Finally, the section concludes with a review of the methods used in this study, and by outlining the study area along with the February 22, 2011 earthquake.
3	Methods	Describes the quantitative methods used for spatial analysis of recorded gastroenteritis cases, earthquake-induced infrastructure damage, liquefaction ground damage and gastroenteritis agent and non-compliant Free Associated Choline (FAC). The qualitative components for interviews are described, including design of the questionnaire.
4	Results	The results for the quantitative and qualitative analysis are summarised using maps and tables. The results chapter identified successful protocols implemented. An extended result section for interview results is provided in Appendices M, N and O that delves onto the details of the interview results.
5	Discussion	Foster discussion on the final coherent outcomes for qualitative and quantitative results. The study's limitations are discussed along with directions for future research are highlighted.
6	Conclusions	Outline whether the research questions were answered. Furthermore, the implications of these findings are also discussed.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The main aims of this multidisciplinary literature review are to understand the current information on Infectious Diseases (IDs) following natural disasters, according to the outline provided below:

- To establish the research questions in a global context by understanding whether IDs occur in the aftermath of natural disasters with a specific focus on increased gastroenteritis prevalence after an earthquake
- To identify significant factors associated with IDs after an earthquake because it may highlight factors to consider in the quantitative analysis
- To understand which factors may have implications for New Zealand's ID management plans, and to assess existing mitigative protocols for ID at Emergency Centres (ECs)
- To collate current preventive protocols implemented to avert those IDs at Emergency Centres (EC) by studying selected case studies which may highlight important factors to consider for qualitative analysis
- To outline the research gaps: what this research will contribute to our current understanding
- To review methodologies used in past studies and to assess whether they may be applicable to answer the research questions
- Recapitulate research objectives and succinct summary of the literature review.

2.2 CONTEXT DEFINITIONS

This section explains in detail the key terms with the purpose of describing how they will be used in the context of this research.

An epidemic is "the occurrence in a community or region of cases of an illness, specific health-related behaviour, or other health-related events clearly in excess of normal expectancy" (Porta, 2008).

Gastroenteritis is a type of Infectious Disease (ID). It is an infection due to the inflammation of the gastrointestinal tract (both stomach and small intestine) caused by pathogenic viruses (Norovirus), bacteria (Escherichia coli, Vibrio Cholerae) and their toxins or parasites (Aghababian, 2010). Norovirus agents account for up to 35% of all acute diarrhoeal outbreaks in the world (DuPont, 1997). Symptoms of infection include combination of diarrhoea, abdominal discomfort, vomiting, and nausea (Hall, 2004). Vomiting is usually the major symptom in children (MOH, 2009). In most cases, gastroenteritis episodes last for 1-2 days experiencing diarrhoea up to 5 stools a day and vomiting, which majority of patients recover relatively quickly (Hall, 2004). Gastroenteritis can last between 1-2 days (or longer) and can affect people of all ages but people who are most susceptible are children under five years, women 20-40 years; and older people (over 60 years) (Aghababian, 2010; Hall, 2004). Sources of gastroenteritis can include contaminated food and water whilst transmission is via faecal-oral routes such as consuming contaminated food or water (Dreyfuss, 2009; ESR, 2012a) The virus can also disseminate through touching contaminated surfaces, objects, and substances (Bruce A. et al., 2009).

An outbreak investigation is one of the main functions of a public health service, especially after a natural disaster. An outbreak refers to an epidemic that is limited to a localised incidence of a disease (like a village or group of people) from a common-vehicle exposure (ESR, 2012a; Gordis, 2000). This research, unless stated otherwise, in specific case studies, outbreaks will be the preferred term. Thus, the study of outbreaks or epidemic is termed epidemiology (ESR, 2012a; Gordis, 2000). This discipline examines disease distribution, and determinant occurrence in a population. Epidemiology is often associated with associated with human mortality and morbidity, particularly in a post-disaster environment. However, mortality is closely associated with earthquake-related injuries after a disaster.

Infectious-disease epidemiology usually involves the following principles within a population (Gordis, 2000): aetiology (cause of disease); disease transmission routes (such as person-person contamination); health factors and population characteristics; and natural prevalence of the disease.

Prevalence is occurrence of the disease (gastroenteritis for this research) by measuring the number of people who have the disease divided by the population at risk of having the disease (Porta, 2008). This is known as prevalence (Porta, 2008). When this measure (prevalence) is associated with a specific point in time, it is referred to as **point prevalence** (Porta, 2008).

Surveillance for IDs in this context uses three different types throughout the literature review. Active surveillance is when a public health professional collects data from health clinics and laboratories (Porche, 2004). Passive surveillance is ID information provided by medical clinic or health care provider (Porche, 2004). Lastly, Sentinel surveillance is when group of public health providers collect data for specific health problems (Porche, 2004).

In this research, epidemics and outbreaks are amalgamated into a single collective group, henceforth, referred to as outbreaks. Gastroenteritis cases (or gastroenteritis prevalence) are viewed as a single group including diarrhoea, bacterial and viral gastroenteritis arising from heterogeneous mix of pathogens aforementioned.

2.3 INFECTIOUS DISEASES AFTER A DISASTER

Assessing whether IDs occur following a disaster within the literature review is very important. This is because it provides international viewpoints and arguments that may need to be considered for this research. The key principles of infectious-disease epidemiology are copiously studied in a post-disaster context, for example studies, from Alexander (1982); Benca et al. (2007); Glass and Noji (1992); Kouadio, Aljunid, Kamigaki, Hammad, and Oshitani (2012); Noji and Toole (1997). The occurrences of IDs after a natural disaster are a highly discussed area. Some authors suggest prevalence of IDs is exaggerated, whilst other authors suggest some presence of influential factors depict IDs after a disaster. Proceeding sections outlines those concepts, which are constantly evolving because of the immense literature present on the subject.

Amongst those suggesting that the prevalence of infectious diseases in the aftermath of a disaster is exaggerated is Alexander (1982), who points out that despite the chaos that eventuated after the Southern Italy earthquake in 1980, there was, lack of disease epidemiology (Alexander, 1982). In 2011, Lemonick (2011) indicated that ID epidemics are relatively rare after natural disasters like earthquakes; in particular, disease transmission from dead bodies is overstated (Lemonick, 2011). Michel, Demoncheaux, Boutin, and Baudon (2007) suggested there is a high level of perceived risk for IDs resulting from chaos after a disaster and media influence amongst a population. Some experts like Orellana (2001) and Seaman (1990) even argue such “fear of epidemics” has led to establishment of unnecessary practices such as non-endemic immunisations. Furthermore, majority of research from authors such as Kouadio et al. (2012) and Floret, Viel, Mauny, Hoen, and Piarroux (2006) has identified there is no direct link to epidemics after natural disasters by conducting a literature review of documented material on databases over a period of 20 years.

However, many factors may promote the occurrence of IDs after natural disasters. In 1992, Aghababian and Teuscher agreed that a region's susceptibility to infection risk increases after a disaster due to disrupted infection control measures in the aftermath of a disaster (Aghababian & Teuscher, 1992). They argue that potential for epidemics to occur always exits; infection risk increases due to amplification of existing transmission routes with the introduction of new pathogens (Aghababian, 2011). Richard et al. (2011) further add that intensity, scope of disaster, infrastructure, and population displacement are related to population health consequences. This notion is shared by Howard, Brillman, and Burkle (1996). Howard et al. (1996) further state the potential for epidemics to occur always exists and that these risks are triggered because of large-scale deterioration of circumstances following a natural disaster, including environmental factors, changes in the distribution of population, and the thriving of endemic organisms, all of which can contribute to a less robust public health response. Dye and Wolpert (1988) provided early historical evidence of a positive correlation between earthquakes, influenza, and three major epidemics of Kala-azar using historical data (from 1875-1950) in India.

Nonetheless, Lemonick (2011) does acknowledge the occurrence of IDs following disasters and proposes that IDs after a natural disaster are more due to lack of resources, disaster systems in place, and areas that are disproportionately affected by disasters (Lemonick, 2011). Watson et al.(2007) also agreed that this "perceived" high disease risk predominately stems from the presence of dead bodies. Michel et al. (2007), agree and further adds that population characteristics, along with disease ecology, are more influential factors. Both teams further suggest that in order to minimise illness associated with outbreaks, especially in high-risk population there needs to be rapid detection and response (Michel et al., 2007).

Similarly, Toole (1992) points out another influential factor: the disaster itself is less important, but the post-disaster situation is more influenced by the secondary effects fostered from the natural disaster. This dynamic drives population displacement, especially overcrowded shelters (such as refugee camps). Thus, the occurrence of ID is most strongly affected by the events following the disaster. Toole (1992) further emphasises that without this factor in place, the threat of communicable diseases is profoundly exaggerated in rapid-onset disasters like earthquakes (Toole, 1992).

Recently, Murthy and Christian (2010) attempts to unify the debates by suggesting that ID prevalence is not related to the magnitude or the intensity of the disaster itself (Murthy & Christian, 2010). Instead, an interrelated combination of pathogens introduced without pre-existing immunity; susceptibility of the population; and increased path transmission (Murthy & Christian, 2010). Furthermore, Murthy et al. (2010) also suggest that areas with high baseline may not greatly increase the incidence of IDs with damaged infrastructure. It is a concept that has been demonstrated from work carried out by Piarroux et al. (2011) from studying the cholera epidemic, caused by the organism V.c*holerae* O1 following the Haiti earthquake. Their work suggests that Cholera was introduced into the Haiti region by asymptomatic Nepalese UN workers (where there was a confirmed outbreak of Cholera at the time in Nepal) coupled with the existing poor infrastructure. The virus used the river as a vector to disseminate pathogens across the Haiti River (Piarroux et al., 2011). People were drinking water from the river, which only added to the population's susceptibility (Piarroux et al., 2011). Because Cholera was not recorded in Haiti for over century, local health institutions lacked the knowledge about Cholera in Haiti (Piarroux et al., 2011). Arguably, this situation demonstrates the implications of emerging pathogens as consequences of natural disasters.

Furthermore, some authors have noted that IDs after a disaster are also time-sensitive. An ID can occur immediately after a disaster or up to several months later. A 5-year study conducted by Bissell (1983) showed that after series of Hurricanes in the Dominion Republic in 1979, there were increased epidemic levels of gastroenteritis in the short-term and typhoid appeared five to six months after the disaster. Thus, ID after a disaster is prone to both the immediate and long-term time frames. Bissell (1983) also re-iterates that the perceived level of low IDs stems from gathering epidemiologic data, and there needs to be a shift in surveillance systems. A viewpoint shared by Waring and Brown (2005), who suggest that there is a greater need for ID surveillance in terms of pre-impact epidemiologic infection. This is a notion reiterated by Howard et al. (1996).

Despite vigorous debates of the past, there is now growing acceptance that ID risk after a natural disaster is greater in developing countries (Toole, 1997; Watson, Gayer, & Connolly, 2007; World Health Organisation [WHO], 2006). For example, in Bangladesh after the 2004 floods, there was a diarrhoeal disease outbreak with more than 17,000 cases reported (Watson et al., 2007). Although as Lemonick (2011) mentioned, it may be argued that natural disasters are common in developing countries, with increased susceptibility of populations, which lack resources and support structures (Lemonick, 2011).

Over the years, a growing consensus has emerged: the risk of IDs after natural disaster is real, but exaggerated for different reasons. Nonetheless, it may be said that most authors have similar viewpoints, albeit for a range of different reasons. These viewpoints on natural disasters leading to IDs are ultimately attributable to the following overarching factors: disaster consequences; population displacement; pathogen transmission; damaged infrastructure; population susceptibility and characteristics; and basal levels of IDs, as opposed to natural disaster characteristics (disaster scale and onset).

Nevertheless, even though the real risk of IDs spreading might be low, as Watson et al. have stated in 2007 and as shown in Table 2-1, Watson et al. (2207) also reiterates that conditions and circumstances can synergistically favour an outbreak irrespective of where the disaster takes place (Waring & Brown, 2005). This is *why* epidemics after natural disasters have taken place in the past. Evidence for outbreaks that have occurred in both developed, (such as Japan) and developing countries (such as Pakistan) is illustrated in Table 2.1. For example, in 1992, Cerro Negro Volcano in Nicaragua eruption plume produced 1.7million tons of ash over three years, covering 200 square kilometres, and leading to acute increased prevalence of diarrhoeal diseases from 13.8 (per 1000 people) to 45.1 (per 1000 people) amongst children (1 yr.) in one week after the eruption (Malilay & Real, 1997).

2.4 EARTHQUAKES: A UNIQUE DISASTER ASSOCIATED WITH GASTROENTERITIS

Each natural disaster is unique. However, an earthquake has few characteristics distinguishing it from other natural disasters. Understanding these characteristics may highlight important factors that heighten the risk of IDs following an earthquake. Isolating this can help provide comparable factors with the February 22, 2011 earthquake.

Notably, earthquakes often have continual aftershocks, especially directly after the main earthquake; this can hinder evacuations and compound existing damage. Thus, earthquakes are one of the main natural disasters that have the capacity to cause immediate casualties (Bartels & VanRooyen, 2012). Earthquakes tend to be concentrated, so populated areas closer to the hypocentre may expect greater damage than those furthest. In addition, subsequent events after the initial earthquake can thwart recovery efforts and increase mortality. For example, the tsunami spawned by the 2004 Indonesian 9.3 magnitude earthquake caused large-scale human casualties of more than 175,000 people (Guha-Sapir & Van Panhuis, 2009). The subsequent event, the tsunami, caused more damage and loss of life than the earthquake itself.

Nonetheless, gastroenteritis incidences have shown to increase after an earthquake. In a previous study of the Northridge California 1994 earthquake, there was an increased incidences of gastroenteritis reported to hospital rose from 80 to 200 in one week after the earthquake at Fernando Valley Emergency Rooms in California (Durkin, 1996). Another example is Chi-Chi earthquake in 1999 where gastroenteritis cases rose compared to basal incidences (K. T. Chen, Chen, Malilay, & Twu, 2003). Furthermore, the Kashmir earthquake in 2005 caused a 20% increase in gastroenteritis incidences (Karmakar et al., 2008). This was likely to be caused by faecal contamination of tap water and springs, which may have been exacerbated by intermittent rain after the earthquake (Karmakar et al., 2008). Coupled with Table 2-1, this suggests that IDs following an earthquake are not rare; instead depends largely on the character and severity of the disaster itself: the risk a real one.

Although IDs such as gastroenteritis are not generally considered to be serious infections, they may spread quickly with the propensity to create a social impact post-disaster (Aghababian & Teuscher, 1992). For example, when Cholera was detected after the Haiti earthquake (albeit 7 months after the earthquake), 1500 patients were presented with symptoms of Cholera within a period of 48 hours at L'Hôpital de Saint Nicolas (Walton & Ivers, 2011). Moreover, gastroenteritis can cause dehydration, particularly in children, due to diarrhoea and vomiting (BMJ, 2009; Desselberger and Gray (2003). In a post-earthquake situation, the water network services may be unavailable, and coupled with short incubation time required for gastroenteritis to develop (minimum 10 hours), gastroenteritis has the potential, in the worst case, to limit human resource capacity during the first few days to weeks following a disaster. For people with gastroenteritis symptoms, a range of actives may become complicated. This can range from staff unable to help at work; being isolated from society when emotional support is needed; and inability to protect one's own family at a distressing time. Thus, ultimately this may propagate a societal response in the aftermath of an earthquake. These reasons highlight that it is imperative to explore factors that may underpin the increased prevalence of an ID's following a natural disaster.

Table 2-1: Examples of infectious diseases following disasters. These infectious diseases events can be due to subsequent events occurring following the disaster. The abbreviations are TSU= Tsunami, EQ= Earthquake.

Disaster Event	Infectious Disease	Country	Year	Source
Tohoku EQ	Diarrhoea (Norovirus), influenza	Japan	2011	(Nohara, 2011)
Haiti-EQ	Cholera, diarrhoea	Haiti	2010	(Abrams et al., 2012) (Pfrimmer, 2010) (Walton & Ivers, 2011)
Bam Earthquake	Respiratory tract infections and gastrointestinal infections	Iran	2003	(Ghorbani, Jafari, & Talebi, 2005) (Honarkar, Baladast, Khorram, Akhondi, & Masoodi, 2005) (Jafari, Radfar, & Ghofrani, 2007)
El Salvador EQ	Diarrhoea	El Salvador	2001	(Woersching & Snyder, 2003, 2004)
EQ	Diarrhoea (transient increase)	Turkey	2000	(Vahaboglu et al., 2000)
Kashmir EQ	Diarrhoea	India	2008	(Karmakar et al., 2008)
Chi-Chi EQ	Respiratory infections and acute gastroenteritis	Taiwan	1999	(K. T. Chen et al., 2003)
California EQ	Coccidioidomycosis Outbreak	United States of America	1997	(Schneider et al., 1997)
California-EQ	Gastroenteritis	United States of America	1994	(Durkin, 1996)
Tohoku TSU	Influenza	Japan	2012	(Hatta et al., 2012)
Aceh TSU	Tetanus, Dengue and Malaria, Respiratory infections (transient increase)	Indonesia	2004	(Guha-Sapir & Van Panhuis, 2009) (Aceh Epidemiology, 2006)
Aceh TSU	Diarrhoea	Thailand	2004	(Guha-Sapir & Van Panhuis, 2009)
Floods	Diarrhoea	China	2007	(Ding et al., 2013)
	Leptospirosis	Brazil	2001	(Barcellos & Sabroza, 2001)
	Diarrhoea and Malaria	Mozambique	2000	(Kondo et al., 2002)
Hurricane Katrina	Diarrhoea, Tuberculosis	United States of America	2005	(Hamilton et al., 2009; Yee et al., 2007)
Hurricane Allison	Diarrhoea	United States of America	2001	(Waring, Reynolds, D'Souza, & Arafat, 2002)
Volcanoes	Acute Diarrhoea	Nicaragua	1997	(Malilay & Real, 1997)
Tornado	Mucormycosis (Cutaneous): Fungal Infection	United States of America	2011	(Prevention, 2012)

2.5 FACTORS THAT HAVE LEAD TO EPIDEMICS IN THE PAST

This section presents a review of critical factors that have led to an epidemic in the past, conditioning the sort of quantitative analysis in the context of the February 22, 2011 earthquake. Although some factors may not be directly associated as an epidemic risk factor, they can contribute to secondary effects, which in turn act to enhance an epidemic risk factor (Toole, 1992). Because of this, an interdisciplinary literature search was necessary to understand the various direct and indirect factors associated with IDs after a natural disaster. Many authors including Landesman (2012) and (WHO, 2006) have outlined many IDs' risk factors, and using these authors as a guide, the most common factors are explored in the following sections.

2.5.1 PRE-EXISTING LEVELS OF AN INFECTIOUS DISEASE

An important factor influencing epidemics is the basal levels of an ID, which is vital to the definition of an outbreak, especially after an earthquake (Schneider et al., 1997; Waring & Brown, 2005). As Murthy and Christian (2010) suggest, countries with high basal levels of IDs due to poor infrastructure may not have increased prevalence of those IDs following a disaster. Likewise, the opposite is also true: countries with developed infrastructure and low basal rates hold the "reserve capacity" to minimise infectious disease risk after a disaster (Murthy & Christian, 2010). Seaman (1990) also noted that areas with high population concentration may have high basal incidences of diarrhoeal illness.

2.5.2 ECOLOGICAL CHANGES RESULTING FROM THE DISASTER

It is vital to consider ecological the factors that have arisen due to an earthquake. Ecological factors are presumptive sources of hazards that may lead to infectious diseases (Lawson, 2001). The most important consequences of ecological changes are those which affect communities living in the aftermath of a disaster. Ecological factors considered in this study are two categories: geological and environmental.

Geological effects have the propensity to cause subsequent events. These subsequent events can range from earthquake-induced landslides, liquefaction, and river avulsion (Dellow et al., 2011; Evans & Bent, 2004). Such factors can in turn result in population displacement. An earthquake-induced landslide is an example of a sequential event that proceeds from an earthquake. In 2001, the El Salvador earthquake (M_W 7.6) triggered a destructive landslide, which swept into a residential area causing 585 deaths and displacing many people (Evans & Bent, 2004). In another example, boulders, rock falls, and rock slope failures induced nearly

100 homes to evacuate as a result of the February 22, 2011 earthquake, (Dellow et al., 2011; Giovinazzi et al., 2011).

Soil liquefaction has been observed in most large earthquakes and often appear as viscous surface flood material; thus, substantially altering the environment (Durkin, 1996; National Research Council Committee on Earthquake Engineering, 1985). Liquefaction ejecta can be contaminated with sewerage—a nutrient rich broth for microbes to harbour ID agents. Work conducted by Institute of Environmental Science Research [ESR] (2012) in New Zealand indicated that E.*coli* can be sustained in sewage-contaminated liquefaction ejecta for up to 5 months, even in the absence of additional sewage contamination (ESR, 2012b). Subsequent geological effects, after an earthquake, can alter the surrounding environment, which in turn can foster ID causing agents.

Subsidiary environmental factors such as weather events after a disaster can amplify or restrict gastroenteritis exposure paths. For instance, a lodge, experienced about 780 gastroenteritis cases with 33% attack rates in Montana United States. Warm weather melted the snow that had been darkened by ash fall from Mt. St. Helens volcanic eruption, a month prior in 1980 (Bruce G. et al., 1983). The melting of ash-contaminated snow resulted in heavy water runoff, contaminating the Montana city water system, which was considered to be the source of the gastroenteritis outbreak (Bruce G. et al., 1983). Likewise, basal rates of gastroenteritis incidents were higher in the hotter, northern parts of Australia (G.Hall, Hanigan, Dear, & Vally, 2011). By studying the spatio-temporal pattern of gastroenteritis over the observational period, they found that for every 5°C rise in temperature across the 8 days, there was a 13% increased risk of gastroenteritis (G. Hall et al. (2011). Thus, temperature and weather can influence IDs.

Another subsidiary factor, although to a lesser extent in New Zealand, is vector-borne disease, and the emergence of emerging zoonotic diseases (WHO, 2005a). Generally, disasters like floods promote favourable breeding grounds due to concentrated organic matter (Wiley & Stephens, 1953). Rodent vectors depend on disaster type, intensity, geographic location, seasonal variation, and existing preventative measures in place (Wiley & Stephens, 1953). Nonetheless, in November 2010, mosquito species (found commonly in Christchurch and Kaikoura areas) were larger in size and numbers due to the fetid, stagnant raised water table bought up by liquefaction following the September 4, 2010 earthquake in North of Christchurch city (Rowe, 2010).

2.5.3 PUBLIC UTILITIES DAMAGES

Water is essential for the maintenance of human health, sanitation, and personal hygiene. Each person requires a minimum of 15-20L per day (Noji, 2005). After a public water shortage in Taiwan, gastroenteritis incidence rose for an average of 15 hours due to contamination occurring during the repairs carried out to the pipe network. This case suggests how important water shortages can be, even for a short time (Huang et al., 2011).

Drinking contaminated water is the ultimate source of IDs (most notably gastroenteritis), and so has been the subject of a great many studies over the years: Bruce G. et al. (1983); Esrey, Feachem, and Hughes (1985); Gupta et al. (2007); Laine et al. (2011); Laursen, Mygind, Rasmussen, and Ronne (1994); McCann, Moore, and Walker (2011). Drinking water from a contaminated well in 1999 led to an E.*coli* outbreak in New York (Watson, Gayer, & Connolly, 2007). Water networks are highly susceptible to earthquakes due to the pipe nodes and pipe leakage (L. Chen, Li, & Ye, 2004). Pathogens that ingressed through broken pipes was the primary cause of Cryptosporidiosis outbreaks and E.*coli* in North America and United Kingdom (Gale, 2001; Swerdlow et al., 1992). Likewise, the Kashmir earthquake in 2005 led to the contamination of the water supply from the stream, tube well, and tap water (Karmakar et al., 2008).

Moreover, uncontaminated water reticulation systems are home to a myriad of microbes, most of which are harmless; yet, some of those microbes are chlorine-resistant (Ingerson, and Reid, 2012). This is important because chlorine is used to remove pathogenic microbes such as E.*coli* (MOH, 2008). In a post-disaster environment, chlorine resistant microbes can contaminate the water by replicating within the water network. Furthermore, WHO's work on preventing the spread of communicable diseases at mass gatherings (particularly evacuation centres) specified that an adequate water supply can improve sanitation conditions and reduce existing gastroenteritis cases by preventing dehydration (WHO, 2008). These studies, thus, highlight the importance of a clean drinking water supply.

Earthquake factors (intensity and soil conditions) can damage a sewerage network leading to a dysfunctional system (Alexander, 1982). In the absence of alternate sewage systems, unsanitary conditions may prevail. This was the case after the M_W 7.0 earthquake on January 12, 2010 in Haiti, where already delicate sewerage system led to further deterioration of the situation (McGarvey et al., 2008). This effect was compounded as people left Port-au-Prince for the surrounding areas; thus, further stressing the already poorly functioning system impending unhygienic practices (Red Cross, 2010). Faecal-oral transmission is the main infectious agent for diarrhoea (Esrey et al., 1985). Hence, improving sanitary conditions by effective excreta disposal methods forms the main barrier to reduce faecal-oral transmission (Lasen et al., 2010). Collectively water and sewerage system forms the major mechanism for large-scale transmission mechanisms to effect a population on a regional scale.

Other important essential infrastructure to consider is transportation. Transport is essential in post-disaster setting, as access to roads, ports, bridges, and rail may be damaged after an earthquake (Chang, 2000; Gordon, Richardson, & Davis, 1998). Earthquake-damaged roads can hinder people travelling to get medical attention (Zhang et al., 2012). Chang and Nojima (1999) further highlighted the need to view separate transportation components—such as road and rail—as a network. The network's performance can play even a larger role when rerouting maps are required to distribute resources following a disaster (De La Torre, Dolinskaya, & Smilowitz, 2012).

Electricity supply is another essential infrastructure. Electricity failure can influence the risk of infection. For example, lack of electricity led to an increased incidence of diarrhoeal illness in New York City in 2003 (Marx et al., 2006). Marx and his team explained in 2006 that the power outage (which lasted up to 3 days) caused a growing concern for public health about consumption of thawed food thereby, acting as an exposure route for ID-causing agents which may have led to diarrhoeal illness (Marx et al., 2006). Hence, essential infrastructure can be a source of both direct and indirect routes for pathogen exposure.

2.5.4 POPULATION DISPLACEMENT

Population displacement in this context refers to large group of people fleeing their homes in order to avoid the effects of a natural disaster. There is mounting evidence that population displacement is a major contributor towards ID epidemics after a disaster. Meticulous work conducted by Toole (1987; 2006), Watson et al. (2007), and WHO (2005b) supports this notion. Population displacement, particularly large volume of people, encourages pathogen transmission due to changes in local ecology (Kouadio et al., 2012). As Kouadio in 2012 suggested, this change in environment can vary from impacts on essential human needs (shelter, water, food) to adjustments to the new biotic environment, which in turn can make people more susceptible to IDs (Kouadio et al., 2012). It is important to note that overcrowded conditions can also occur at households, thereby encouraging the spread of IDs (Baker et al., 2012). Although large population migration is usually associated with refugees moving into crowded refugee camps because of civil war as Toole (2007) implies; mass migration can take place after natural disasters. Yet, person-to-person transmission was associated with increased incidence of Norovirus gastroenteritis since 2002 even in cruise ships (Cramer, Blanton, & Otto, 2008).

Mostly a household does not constitute homogeneous individuals; instead a household is a macro-representation of a community, and composed of heterogeneous individuals with varying degree of infection disease vulnerability. Overcrowding in a household can lead to infectious disease spreading without the influence of earthquake effects (Baker et al., 2010). However, it can be argued these conditions are heightened immediately after an earthquake. Different structures of the population can affect the overall “herd immunity,” which is important in disease tolerance as a whole within a population (Kun et al., 2010).

2.5.5 POPULATION DEMOGRAPHIC

Population demographics can also influence IDs following a natural disaster. An important population composition is the disabled community requiring special care which can be vulnerable to infectious diseases, especially if level of independent care is low (Paton & Johnston, 2006). After the Great East Japan Earthquake, medical treatments were given without producing a disability certificates and specific clinics for disables people were available to cater specific needs (WHO, 2011a). Likewise, other population compositions such as young children, especially those still dependent on adults for care, are also vulnerable to IDs (Bruce A. et al., 2009).

Elderly is defined as a person who is older than 65 years of age and is vulnerable to disaster effects (Fernandez, Byard, Lin, Benson, & Barbera, 2002). As Fernandez explains, elderly within a population can increase vulnerability to an infectious disease after a disaster due to their impaired physical mobility and chronic health related conditions, which limits an individual’s independence to cope in post disaster setting (Fernandez et al., 2002).

2.5.6 SOCIOECONOMIC STATUS

Socioeconomic status is an important factor of infectious disease incidences. Work conducted by Baker et al (2012) shows that socioeconomic disparities are related to hospital admissions for infectious diseases in New Zealand. Hence, under additional stresses in the aftermath of an earthquake it can have a brimming effect within a society. Further Kun et al (2010) conducted a survey study to elucidate that after an earthquake, disease prevalence is common amongst low-income households. Tearfund (2005) have stated that disasters widens the socioeconomic gap due discrepancies in resources available (Tearfund, 2005). Such inequalities leads to asset erosion within in a household after a disaster (Cosgrave, 2008). Although this is more evident in developing countries, Baker et al (2012) have shown that such situations are growing as part of the population composition within New Zealand (Baker et al., 2012). Increasing incidence in several categories of infectious diseases is most likely to be caused by fundamental social determinants (income variation), housing conditions, and access to health services (Baker et al., 2010).

Overall the aforementioned factors can operate synergistically and successively (or indirectly or directly) to influence IDs such as gastroenteritis, after natural disasters like an earthquake. These and additional factors encountered from the literature review are summated in Figure 2-1. The figure represents the ambit of ID causing agents, exposure paths (both indirect and direct), and population characteristics that can give rise to an ID after a disaster. Given the combination of those factors that can evoke people to leave their home and seek many types of emergency shelters are shown in Figure 2-1.

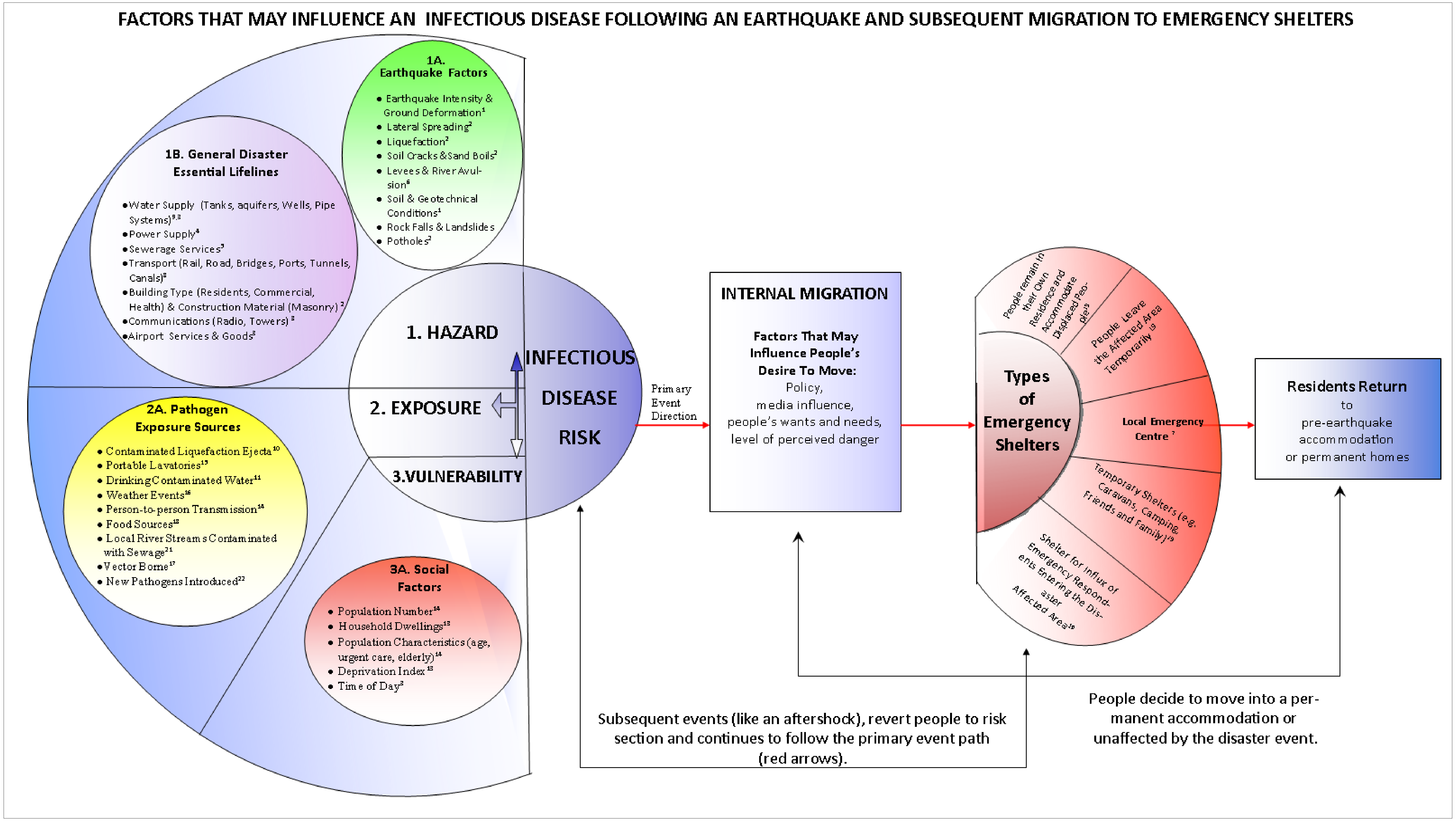

Figure 2-1: Summarises the indirect and direct factors that may lead to an infectious disease following a natural disaster and the subsequent migration to emergency shelters. The indirect factors are hazard and vulnerability whilst the direct factors are the exposure routes identified. The arrows depict migration routes people may choose to take following a natural disaster. The references to foot notes are given below.

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2.6 NEW ZEALAND CONTEXT

The case study for this research is located in Christchurch. Therefore, it is important to obtain a working knowledge on the existing prevalence of gastroenteritis, and of existing ID management plans in New Zealand (NZ) because it can provide information on existing protocols and give context to the research. This in turn can inform methods or isolate areas in need for further studying.

2.6.1 GASTROENTERITIS PREVALANCE AND PUBLIC HEALTH IN NEW ZEALAND

In New Zealand, it is estimated there are 4.66 million cases of nonspecific gastroenteritis cases in one year with about 53,000 cases of Norovirus gastroenteritis per year, which means that every person experiences gastroenteritis, to some degree, every year (Bruce A. et al., 2009; Lake, Baker, Garrett, Scott W.G., & Scott H.M., 2000). In New Zealand, gastroenteritis can last up to 171 hours in the absence of a post-disaster environment (MOH, 2009) . Arguably, it may be considered that infection period can be elongated if access to sanitary conditions and fresh water supply is hindered in a post disaster setting. In 2006, there was a waterborne outbreak (with excessive E.*coli* readings of 7.4-220/100mL in the drinking water supply) at Cardorona ski field in 2006 which was attributed to water contaminated with sewerage (Ball, 2006).

In New Zealand, notifiable gastroenteritis cases are recorded from mandatory reporting from medical practitioners to the Notifiable Disease Surveillance System in New Zealand, which is managed by ESR on behalf of Ministry of Health (Ball, 2006). Not all gastroenteritis cases are notifiable, and the criteria for notifiable gastroenteritis cases in NZ are outlined in MOH (2012b). Gastroenteritis cases arising from E.*coli* strains causing diarrhoea are considered to carry high public health importance in New Zealand (MOH, 2012b). Nonetheless, NZ also has a plan in place for informally-reported cases of gastroenteritis and outbreak management plan using both passive and active surveillance systems for public health officials (ESR, 2012a).

2.6.2 PUBLIC HEALTH RESPONSE ARRANGEMENTS AFTER A DISASTER IN NEW ZEALAND

In New Zealand, 20 regional District Health Boards (DHB) encapsulate the health system across the country as part of the health and disability sector within Ministry of Health (Community and Public Health [CPH], 2013). The health board pertaining to the Canterbury region is known as the Canterbury District Health Board (CDHB). The CPH is a part of the CDHB provides the public health services in New Zealand (CPH, 2013). In the aftermath of the February 22, 2011 earthquake, the CPH operated jointly with Ministry of Defence Emergency Management (MCDEM) at multiple organisational levels to protect the public against continual public health challenges. The challenges included infectious diseases, drinking water, sewage and housing (CDHB, 2012). The New Zealand CDEM promotes, co-ordinates, and provides local; and national emergency response in NZ.

2.6.3 EMERGNECY CENTERS IN NEW ZEALAND

According to 2010 Ministry of Civil Defence Emergency Management (CDEM) Act in New Zealand welfare means:

> "The response the CDEM sector and their welfare partner agencies will deliver to those people (individuals, families/whanau and communities) directly affected by an emergency. This includes provision of food, shelter, clothing, financial assistance, psychosocial (psychological and social) support and extends throughout response and recovery"

Hence, an Emergency Centre (EC) (or otherwise known as emergency shelter or welfare centre) forms an essential component of the public health response by providing essential goods and services to those affected in a post disaster environment. For example, consider the welfare response during the plight situation after the February 22, 2011 earthquake. The earthquake caused major damage to homes, water, and sewerage systems (Giovinazzi et al., 2011). In response, several pre-planned emergency centres (Burnside High School, Cowles Stadium, Pioneer Stadium, and Rangiora) were opened (Dell, 2012). During the initial days following the earthquake, several hundred people were accommodated at these sites (Dell, 2012; McLean I., 2012). The ECs recorded no infectious disease transmission internally, although a small number of families arrived at emergency centres with pre-existing symptoms of gastroenteritis (Dell, 2012; Johnston, 2012). This further reiterates the importance of investigating one of the main aims of this project: to investigate interventions that successfully prevented a gastroenteritis outbreak within an emergency centre. The results of this literature review did not uncover any further cases of disasters in NZ, where ECs have been opened because of a disaster response, besides the September 4, 2010 and February 22, 2011 earthquakes. However, NZ has a national pandemic plan, which was put in place as the country's template for dealing with infectious diseases after the emergence of pandemic influenza.

2.6.4 NEW ZEALAND INFLUENZA PANDEMIC PLAN

In 2009, WHO declared the first pandemic in 41 years, estimating that 18% of New Zealand's population was infected with pandemic Influenza A (H1N1) (Bandaranayake et al., 2010). Non-seasonal influenza became notifiable, which enabled to isolate 3211 cases (Bandaranayake et al., 2010). As a result, the cases were reported to the national notifiable disease database (Bandaranayake et al., 2010). Due to societal and economic impacts, and the threat to health service delivery, the MOH released a revised Influenza pandemic plan in 2010 including provisions for welfare care (MOH, 2010). Within this document, contaminant measures were included to limit pandemic dissemination of pathogens (MOH, 2010). They included border management strategies due to the unique NZ geography; cluster control from strict surveillance; provisions restricting the movement of isolated communities where no cases of infection are observed; hygiene measurements; and social distancing (closure of children's education institutes). The guidelines are kept general so professionals are able to operate as the situation evolved. These actions are now embedded into the overall New Zealand influenza plan 2010 (MOH, 2010).

Nonetheless, on an international scale, case studies have provided evidence of gastroenteritis outbreaks that have occurred at evacuation centres following a natural disaster. This is important to the present research because the documented case studies may highlight important issues that can prevent ID outbreaks at ECs. Case studies have isolated important lessons: contamination sources, interventions carried out to limit pathogen dissemination and lessons collated from those experiences. It is important to note that one of those lessons gaining growing acceptance is to establish smaller functioning emergency centres, which seemed to be preferred compared to the larger emergency centres (McLean I., 2012; Mitchell, 2012). A notion that is supported by WHO because of the apparent increased interpersonal relationship and privacy (WHO, 2011b). Arguably, this option may help to alleviate overcrowding issues: a large factor associated with communicable diseases (Toole, 1997).

2.7 EMERGENCY CENTRE INFECTIOUS DISEASES AND WELFARE SURVEILLANCE

Noji (2005) has shown that up to 80-90% of the 200,000 displaced people, after the Nicaragua earthquake in 1972 stayed with relatives. Despite this, even minimal population displacement can lead to overcrowded shelters Toole (1992). Thus, shelter type influences overcrowding. Overcrowded shelters increase the number of people exposed to an infection, especially in winter months (Aghababian, 2010). Other factors such as compromised personal hygiene like hand washing can wane in importance due to scarcity of clean water and soap. Plotinsky et al. (2006) showed how basic hygiene practised in a Texas EC after Hurricane Katrina, and believed it was a major factor that contributed to the absence of a gastroenteritis outbreak (Plotinsky, 2006). Moreover several authors have suggested the importance of establishing surveillance as a preventive protocol, especially syndromic surveillance in absence of laboratory resources in a post-disaster environment (WHO, 2008). Toprani et al (2006) also supports the above notion by highlighting the importance of direct surveillance at ECs, in addition to sentinel and active surveillance, at the "Megashelter" during Hurricane Katrina in 2005. It is also considered that syndromic surveillance is better because the surveillance can operate with limited public health resources and cater to specific evacuation centre characteristics (such as different demographic features, number of evacuees, health status) (Toprani et al., 2006).

Hence, the Centre for Disease Control and Prevention (CDC) has implemented a shelter assessment tool to assess evacuation shelter conditions (CDC, 2012). Primarily aimed at environmental health practitioners, the tool aids in identifying environmental conditions, recording data for future planning, health and safety issues, and establishes a hierarchy of priorities. Furthermore, the tool can be used as a supplement for current protocols (CDC, 2012). New Zealand has an adapted version of the shelter assessment that was carried out at some Emergency Centres (EC) after the February 22, 2011 earthquake (Dell, 2012). Nevertheless, the templates such as the checklists derived from experience can be invaluable in a post-disaster setting. Often, this information can be incorporated into a larger assessment framework unique to each region because it can share data between evacuation centres (Toprani et al., 2006). Another similar checklist is also available through the Sphere Project (The Sphere Project, 2011).

For welfare surveillance, The Sphere Project is a self-regulatory tool comprising a voluntary code for effective humanitarian relief (The Sphere Project, 2011). The guide contains a set of minimum standards, followed by key actions to achieve those standards (The Sphere Project, 2011). Key indicators are given to assess progress towards the standards. The project has a generalised format; so, it is applicable for various types of disasters that require humanitarian assistance. However, the project does not provide information on ‘how’ to achieve the set standards. The key message is that for different disaster situations, customised methods are required. Nevertheless, it is a valuable tool as it caters to ground floor staff whereas WHO programmes appear to cater for national and global scales. The following international case studies are examples that were set up following a natural disaster that have implemented protocols to prevent ID outbreaks at ECs. An analysis of these case studies can isolate vital overarching protocols to be investigated in this research.

2.7.1 THE GREAT JAPAN EARTHQUAKE

A magnitude 9.0 earthquake stuck Japan on March 11, 2011 produced a tsunami (WHO, 2011b). Sendai city, in the Tohoku region, was one the worst affected areas and the tsunami that followed took 15, 848 lives (WHO, 2011a). Despite extensive disaster preparedness programmes, the sheer intensity of the tsunami destroyed basic infrastructure and displaced more than 440,000 people into 2398 evacuation centres (WHO, 2011b).

There were 300 emergency shelters in Ishinomaki City made available for evacuees on March 16th after the water had receded (WHO, 2011b). During the first week, evacuation centres were functioning without running water and power with depleting basic supplies (WHO, 2011a). There was a growing need for pharmaceutical supplies, as many of the elderly had no access to essential routine medications such as diabetes. It took two weeks to put in place a public health response to staff loss and resource shortages (WHO, 2011a) (WHO, 2011b). By March 17th, after one week, cases of gastrointestinal infection and influenza-like illnesses were reported, and continued to be reported into week three (Takahashi, Goto, Yoshida, Sumino, and Matsui (2012); WHO (2011b). Shiogama detected gastroenteritis incidences as well as other communicable diseases (such as respiratory diseases) and non-communicable diseases (WHO, 2011b).

Two outbreaks of influenza occurred at two of the evacuation centres at Miyani Prefecture (Hatta et al., 2012). Kanamori et al (2011) believed that many evacuation centres had poor environmental maintenance, unsanitary conditions, and inadequate disposal of infectious waste including faeces and nappies (Kanamori, Kunishima, Tokuda, & Kaku, 2011). It was found that evacuees were sheltered in crowded conditions (less than 1-2m spacing). In addition, poor air ventilation, reduced hand hygiene from limited water supply, and absence of the public health system immediately following the event had contributed to increased pathogen transmission (Kanamori et al., 2011). From March 23, 2011 to April 10, 2011, 8 out of 16 centres reported 1-42 cases of gastroenteritis with cases numbers declining soon after (WHO, 2011b). Prompt action was taken within all the evacuation centres to minimise pathogen dissemination, which are highlighted in Table 2-3.

In addition, daily surveillance using mobile phones in 40 large-scale evacuation centres was established (Yuzo, Tamano, Partridgea, & Kasaia, 2011). In fact, using mobile phones has been shown to be an effective method of ID surveillance following a disaster (Yang C., Yang J., Luo, & Gong, 2009). It enables the amalgamation of disease-resistance environments and implementation of infection control measures (WHO, 2011a). Emergency shelter assessments were conducted by medical response teams (WHO, 2011a). Evacuation centres were utilised for long a time; even on May 11, 2011 there were still 79, 776 evacuees housed in 901 evacuation centres (WHO, 2011a). As the summer months approached and evacuees began to cook at the ECs, food safety education was provided (WHO, 2011a). However, based on post-surveillance data, no major communicable disease outbreaks were reported in the affected evacuation centres (WHO, 2011b). This suggests that most cases were sporadic, or by the time syndromic systems were available, most of the initial gastroenteritis clusters had waned. Thus, establishing early syndromic surveillance at the outset should be a key priority for disaster management plans.

2.7.2 HURRICANE KATRINA

In 2005, Hurricane Katrina caused extensive calamity and displaced thousands of people. As a result, on 31st of August, a “Megashelter”, the Reliant Park Complex, was used to house about 27,000 evacuees (Yee et al., 2007). The shelter contained essential food, water, shelter and a temporary clinic staffed with local hospital district. Within three days, there was increasing acute gastroenteritis incidences (defined as vomiting and/or diarrhoea), and an outbreak was confirmed soon after (Figure 2-

2). The gastroenteritis outbreak consisted of multiple strains of Norovirus that affected more than 1000 evacuees of all ages (Yee et al., 2007). Further microbial analysis of stools suggested that multiple exposure routes acted as infection sources. Thus, cocktail of interventions were used to reduce gastroenteritis incidences (Figure 2.2). As the number of reported cases rose, the allocation of various resources (such as soap, paper, and hand sanitisers) was increased (Yee et al., 2007). Immediate introduction of interventions commenced (Figure 2-2) in a similar fashion to the Great Japan Earthquake. They included educating evacuees on hand-washing; increased number and maintenance of portable lavatories; and cleaning with bleach-based cleaning products (Yee et al., 2007). Although the number of cases decreased towards the final closure days, there were still incidences of Norovirus gastroenteritis, which continued until the clinic at the Megashelter was closed. At the Megashelter, the initial syndromic surveillance was conducted using a checklist for general disease trends including diarrhoea and vomiting, which in turn were fed into a generalised database to obtain morning reports for the incident command centre, medical staff, and other officials (Yee et al., 2007). This highlights how crucial it is to implement preventive measures before an outbreak is identified.

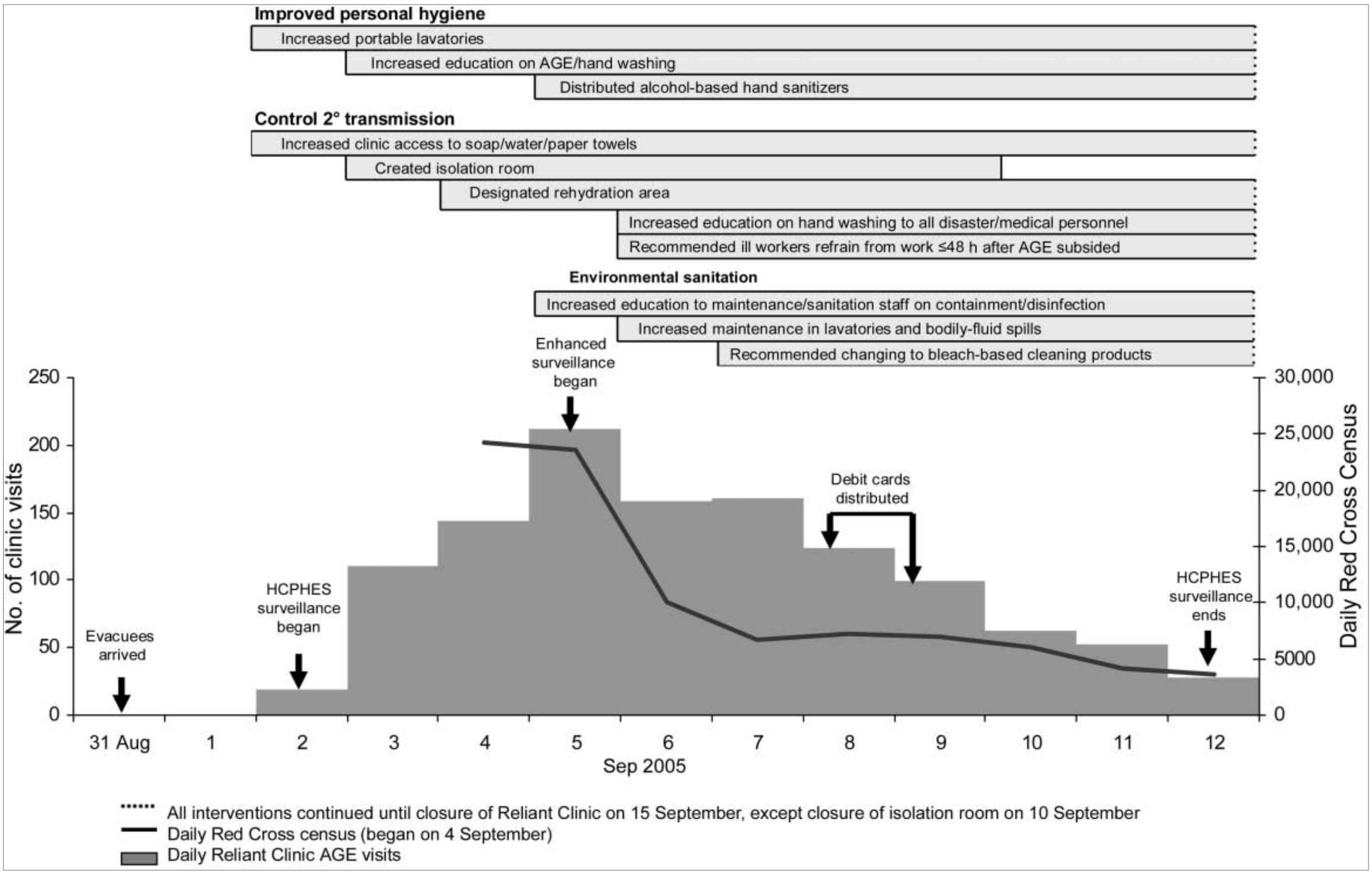

Figure 2-2: Depicts the timeline for epidemic curve for Norovirus gastroenteritis outbreak, interventions and events at the Reliant Park Complex "Megashelter" between 2-12 September 2005 (Yee et al., 2007).

2.7.3 SUMMARY OF INFECTIOUS DISEASE PREVENTION EMPLACED AT EMERGENCY CENTRES

Here follows a summary of the main aspects of gastroenteritis interventions implemented at ECs along with an account of some additional literature to promote better health conditions at ECs.

Table 2-2: Summary of preventive protocols to avert gastroenteritis outbreaks at emergency centres.

Preventive Intervention	Description	Source
Clean Water	Provide clean drinking water for personal use (for staff and evacuees).	(International Association of Venue Managers Inc [IAVM0], 2010) Landesman (2012); Ministry of Health (2010); Rebmann (2007-2008); The Sphere Project (2011); WHO (2006, 2008, 2011a); Yee et al. (2007)
Functional Sewerage System	Appropriate measures for excretion disposal (includes medical waste and rubbish disposal) and chlorine-based cleaning for bathrooms. One lavatory for every 20 people for short-term accommodation.	
Hand Washing	Make available multiple hand washing options, which includes alcohol-based hand sanitisers, foot-operated soap and water hand washing systems. Maintain availability of alcohol disinfectants at the entrance of shelters and in dining areas. One hand-washing fixture for every 15 people.	
Ventilation and Bedding space	Provide appropriate ventilation especially in sleeping area with 40-50 feet of air space for a person.	
Strong leadership	To maintain order and morale.	
Psychosocial support with support services	Provide morale and mutual support to promote recovery.	
Public health surveillance	Syndromic surveillance with active and sentinel surveillance systems.	
Public Health education	Educate evacuees using posters, handouts and announcements. Encouraging use of face marks.	
Provide health clinics and public health personnel	This includes medical staff such as a nurse to maintain good public health practices and conditions in the shelters, and to report any potential outbreaks/incidences through surveillances. The clinics should also house mass dispensing plans for emergency medications (such as insulin for diabetes, and epidural pens for adverse allergy reactions).	
Isolation units Management	Incoming evacuees into the evacuation centre should be screened for fever, cough, skin rash, vomiting, and diarrhoea. If one of these conditions is met then a room in advance should be used to house evacuees awaiting evaluation or transfer.	
Child care facility	Educate evacuees on sanitary procedures and nappy changing stations.	
Shower facilities	Provide shower facilities to maintain body hygiene. One shower for every 15 people.	

2.8 RESEARCH GAPS IDENTIFIED

In the light of many viewpoints about which influential factors most affect an infectious disease following a natural disaster; it is vital to view the consequences of disasters (such as earthquakes) as unique events. For example, the subsequent effects of an earthquake on the exposed population are modified by the highly contextual local factors which extend across the environment, infrastructure damage, geological conditions, and the population demographics. Thus, the February 22, 2011 earthquake is unique and needs to be examined.

Gastroenteritis prevalence is one of the effects following an earthquake, which can depend on those factors demonstrated by Kouadio et al. (2012); Lemonick (2011); Michel et al. (2007); Toole (1992); Watson et al. (2007). However, little work has been attempted to link gastroenteritis prevalence, geologic conditions, and infrastructure damage. Therefore, this thesis studies the February 22, 2011 earthquake in this manner in an attempt to spatially assess the factors that may underpin gastroenteritis prevalence after an earthquake; specifically for a case study following widespread water and wastewater infrastructure damage.

Christchurch had no reported outbreaks of gastroenteritis to the NZ disease surveillance system following the February 22, 2011 earthquake (Dell, 2012; MOH, 2012a). However there were confirmed cases of people arriving at ECs with gastroenteritis symptoms (Dell, 2012). Therefore, it is beneficial for the national and global knowledge base to understand what preventive steps were practiced at ECs to prevent gastroenteritis spread, or, originated within an EC. Furthermore, public health and emergency operating centres have begun to develop an emergency gastroenteritis plan (Dell, 2012). Timely research on such topics is highly important following a disaster because information can be lost due to factors such as population mobility and memory loss. If this happens, then an opportunity to learn from a practical experienced event, which has low probability occurrence with high consequence, is lost. In short, a vital learning curve missed.

2.9 METHODOLGY REVIEW

Implementing a methodology to answer the research questions involved evaluating literature for appropriate methods for quantitative and qualitative research questions.

2.9.1 QUANTIATIVE SPATIAL METHODS

From a disaster management perspective, a multidisciplinary approach must be adapted beyond the realms of morbidity and mortality to address IDs after an earthquake. However, for communicable diseases there is limited information on how to represent the interaction with different factors in a synergistic manner. This is most likely due to two main reasons. First ID incidences tend to occur from multi-exposure routes. Interconnected routes vary in intensity exposure to different factors. Second, during an earthquake, factors that are more distal can be enhanced due to subsequent events from an earthquake (like liquefaction and landslides). Understanding this synergistic interaction from a spatial viewpoint is a major component in this project using Christchurch earthquakes as a case study. Some authors have attempted to show this interaction. For example, work conducted by Emmanuel et al (2011) and (Gilbert & Pfeiffer, 2012) used landscape epidemiology to derive spatial maps by understanding geologic and vegetation conditions that enable disease transmission using GIS technology.

Over the past decades, there have been various disease mapping and spatial regression methods some of which are reviewed by Auchincloss, Gebreab, Mair, and Diez Roux (2012); (Rushton, 2003), (Fischer & Getis, 2010) (Daniel, 2005). Disease mapping is concerned with calculating relative risk estimates whilst spatial regression considers the relationship between relative risk and potential risk factors (Wakefield, 2007). Table 2-3 shows range of these methodologies and their applications. As evidenced by Table 2-3, the studies vary from disaster-based studies (Piarroux et al. (2011) to spatial distributions of infections (Hu, Clements, Williams, & Tong, 2011), and explorations of population characteristics (Saurina et al., 2010). It appears that G-statistics and Moran's *I* statistic are the most commonly used methods for detecting spatial clustering. The Besag–York–Mollié (BYM) model seems to be a popular choice for spatial regression. These spatial applications were mostly depicted by the software available and the type of data considered in the study.

Three particular cases from Table 2-3 show similar research aims to those of this study, but under different research contexts. Kingston and Semple (2005) investigated gastroenteritis outbreak and water-borne disease transmission routes in an outbreak of gastroenteritis in Jamaica. In a similar fashion, Sarker et al. (2007) investigated the relationship between gastroenteritis and faecal contamination of the water supply. Both studies' research questions resemble this study's quantitative component, but, in the absence of a post-disaster context. However, that post-disaster context resembles the study by Piarroux et al., (2011), who investigated cholera in the context of the Haiti earthquake. The Haiti earthquake had a similar magnitude and depth to those of the February 22 2011 earthquake in Christchurch.

Table 2-3: Examples of spatial methods used to study spatial patterns of disease.

Disease or Outbreak Studied	Study Location	Global or Local Moran's *I* Statistic (Spatial Autocorrelation)	Getis-Ord General (High/Low Clustering in ArcGIS) or Getis-Ord Gi* (Hot-Spot-ArcGIS)	Regression Models	Other Analysis Methods	Source
Spatial analysis of Haemorrhagic fever with Renal Syndrome	China				"Spatial Scan Statistics" were applied using a likelihood function in SaTScan software.	(Fang et al., 2006)
Ecologic study to investigate the association between cancer mortality and proximity to incinerators; and hazardous waste treatment plants	Spain Towns (1997-2006)			Using Besag–York–Mollié (BYM)		(García-Pérez et al., 2013)
Spatial relationship between Verocytotoxige-nic *Escherichia coli* (VTEC) incidence and livestock density	Ontario, Canada			Ordinary Least Square (OLS) Maximum Likelihood Estimation (MLE)	Cartographic outputs	(Gyles, 1999)
Spatial analysis of notified Dengue fever infections	Queensland Australia			Logistic Regression Models- empirical Bayesian analysis	Choropleth maps Local indicators of spatial association (LISA)	(Hu et al., 2011)
Spatial analysis of notified Cryptosporidiosis infections	Brisbane, Australia			Spatial Empirical Bayes Rates Smoothing Spatial Classification and Regression Tree (CART)		(Hu, Mengersen, & Tong, 2009)
Spatial patterns of Dengue	Chachoeng-sao Province Thailand				Tracking Analysis Local indicators of spatial association (LISA) Kernel Density Estimation method	(Jeefoo, Tripathi, & Souris, 2010)
Spatial and temporal trends for Lymphoblastic Leukaemia and Type 1 diabetes				Using Besag–York–Mollié (BYM) with CAR Model for spatial effects		(Manda, Feltbower, & Gilthorpe, 2009)
Spatiotemporal analysis to understand social and environmental drivers of Malaria risk.	Vietnam			Zero—inflated Poisson regression models		(Manh et al., 2011)
Spatial association between Larynx cancer and socioeconomic conditions between 1994-2004	Girona (Spain)			Using Besag–York–Mollié (BYM)		(Saurina et al., 2010)
Epidemiological investigation of an outbreak of acute diarrhoeal disease	India			Scan statistic using a Poisson Model (Kulldorff, 1997)	Spatial Clu8steres using SaTScan	(Sarkar et al., 2007)
Geographic clusters and risk factors associated with gastroenteritis	Kingston, Jamaica			Regression analysis using SPSS Software	Kernel Density	(Kingston & Semple)
Cholera Epidemic mapping	Haiti			Regression Model with spatial variability-Quasi-Poisson Model	Spatial Clustering using SaTScan Spearman Correlation	(Piarroux et al., 2011)
Diarrhoeal illnesses associated with Water Supply	North Rhine-Westphalia, Germany				Incorporated a Water-Supply-Structure-GIS model (WSS-GIS) (Kistemann, Herbst, Dangendorf, & Exner, 2001)	(Dangendorf, Herbst, Reintjes, & Kistemann, 2002)

2.9.2 QUALITATIVE APPROACHES

The following section reviews possible methods that may be used for the qualitative analysis in this research. Amongst the variety of qualitative research methods, there appear to be five popular methods: phenomenology, narrative research, ethnography, case studies, and grounded theory (Creswell (1998); Patton (2001)).

Phenomenological research explores the particular narrative of an individual (Creswell, 1998). For example, work conducted by Hearns and Deeny (2007) using the phenomenological approach to understand support for aid workers after complex emergencies. Similarly, the narrative method mainly involves studying a phenomenon or a method (Silverman, 2013). For instance, Tuohy and Stephens (2012) used narrative theory to explore how flood stories in 1999 disaster are told. Ethnography is affiliated with developing patterns of beliefs, behaviour and language (Creswell, 1998). One example of this is the work by Shrum, Duque, and Ynalvez (2007) which used video ethnography to understand infrastructure damage using Hurricane Katrina. A case study explores issues researched within a context or a situation. For example in New Zealand, a case study was used to understand the pandemic H1N1 Influenza (Williams, Begg, & Burgess, 2010). Finally, Grounded Theory (GT) refers to an explanation or a process unpacked through the analysis of qualitative data (Creswell, 1998). For example, GT was applied to understand evacuation decisions in impoverished areas after Hurricane Katrina (Eisenman, Cordasco, Asch, Golden, & Glik, 2007).

These five methods have similarities and differences between them. Similarities include research approaches for data collection and the research process, such as data collection, analysis strategies, and overall conclusions (Creswell, 1998). For all of the aforementioned methods, there are multiple sources of data collection, like interviews (semi-structured and structured), participant observation, field notes, and journals (Marshall & Rossman, 2010). The Phenomenological and narrative based approaches involve a single person or phenomenon from a descriptive perspective. Although useful, most are not appropriate methods to answer this study's qualitative research question.

However, GT and case study approaches are able to answer the question, but GT seems to be the best approach. This is because GT specifically asks *what* or *how* by studying an action (or a process) involving participants' views—the essence of this study's qualitative research question (Creswell, 1998) (Bitsch, 2005). Combined studies using GT have been conducted in the past, such as Rudolph and Repenning (2002); and Thornberg (2012). However, it is difficult to compare the GT methods implemented between different studies, because of the context-specific qualitative data involved. Thus, GT has been adapted to suit the data. However, over the years different GT viewpoints have emerged which are considered important to understanding the underlying concepts in order to select the best suitable method for qualitative part of this research.

2.9.3 GROUNDED THEORY

Since GT's inception, the methodology steps have remained more or less constant, but two divergent viewpoints that underpin the principles have emerged over the years. Whilst Glasser promulgated the so-called "classical" variant of theory, Strauss and Corbin transformed classical GT into a more analytical approach. Recent and progressive work from Strauss and Corbin explains delineated steps on how to conduct, analyse, interpret and verify data to develop a theory (Corbin and Strauss, 2008, Strauss and Corbin, 1994, Strauss and Corbin, 1990). In doing so, Strauss and Corbin aimed to make GT more palatable to various scientific fields and cater to mixed-methods approaches using qualitative and quantitative methods within a study. Strauss and Corbin also permits literature review as a starting point for data collection and use the literature review to verify the theory from a broad perspective (Corbin and Strauss, 2008).

On the other hand, Glasser's state that using the literature review changes the traditional comparative approach of GT, because it gives the investigator preconceived ideas which consequently demote analysis and any emerging theories from those data. Thus, Glasser advocates leaving the literature review as the last step in GT methodology—to prevent contaminating the newfound theory. In the same tradition as Glasser's approach, Charmaz (2006) has put forward a limbic GT approach, which promotes the idea that GT only serves as a set of guidelines, which are adaptable to suit the research objective(s); because, theories are developed form an interpretive point of view form participants (Charmaz, 2006). Innumerable authors have compared these divergent views of GT approaches, and offered many viewpoints on GT (Duchscher & Morgan, 2004; Heath & Cowley, 2004; Laws & McLeod, 2004).

However to cater to this study's research objectives, Strauss and Corbin's (2006) approach was used whilst acknowledging Charmaz's viewpoint that theories developed are an interpretive portrayal only. Strauss and Corbin's methodology better suited the research question and the mixed methods style of the study. More importantly, it was imperative to select a methodology that suited the research question and data; not the reverse.

2.10 LITERATURE REVIEW SUMMARY

- Infectious Diseases do occur following a disaster globally, and why they occur is of great interest, with both divergent and similar viewpoints

- Even though "fear" of IDs have led to misperception of IDs' risks occurring following a disaster, there is a collective consensus from many authors that IDs tend to occur because of the subsequent consequences following the disaster and other associated factors

- The associated factors include: disaster consequences; population displacement; pathogen transmission; damaged infrastructure; population susceptibility and characteristics; and basal level of an ID

- The factors that may give rise to gastroenteritis after an earthquake, and which are highlighted in Figure 2-1 include: contaminated water, pre-existing levels of gastroenteritis, weather, population displacement, and poor surveillance

- New Zealand has about 4.66 million cases of non-specific gastroenteritis cases in one year, and there is mandatory recording of notifiable gastroenteritis cases according to the MOH criteria in New Zealand, and the outbreak plan such as the H1N1 Influenza pandemic in 2009 serves as the most significant outbreak in NZ

- There are past outbreaks of gastroenteritis following an earthquake, especially at ECs (Table 2-2), and the results of this literature review indicate in NZ, no EC plan has been activated to the scale of the February 22, 2011 earthquake

- Protocols practiced to prevent gastroenteritis at ECs after disasters include hand washing, portable lavatories, surveillance for IDs, clean drinking water, and educating evacuees

- The research gap is the need to incorporate quantitative and qualitative methods to study a unique disaster fingerprint

- A review of the methodological literature indicated that for spatial statistics, Moran's *I* statistic, Hot Spot analysis, and Besag–York–Mollié (BYM) model were most commonly used with Grounded Theory using Corbin and Strauss (2008) guidelines was best for qualitative component of this research.

Thus, given the vast scale of damage and the urgency that surrounded Christchurch city in the aftermath of the February 22, 2011 earthquake, there were no recorded gastroenteritis outbreaks (Dell, 2012). This coupled with diverse literature on issues and examples relating to infectious disease following a disaster highlight how important it is to explore the research questions underpinning the present work.

CHAPTER 3: METHODS

3.1 INTRODUCTION

This chapter describes the methods used to assess the two thesis aims: the first was to assess whether earthquake-induced infrastructure, liquefaction ground damage (lateral spread and surface flooding), and gastroenteritis agents spatially explained the recorded gastroenteritis cases after the February 22, 2011 earthquake. The second, to identify the preventive protocols implemented at the ECs following the February 22, 2011 earthquake that averted gastroenteritis outbreaks. The former used quantitative methods whilst the latter applied qualitative approach. The following sections comprehensively describe methods utilised for quantitative and qualitative analysis.

3.2 QUANTITATIVE ANALYSIS

The literature review identified the significant factors that can contribute to increased gastroenteritis prevalence after an earthquake. This guided data collection efforts. For example, the literature review has shown that damaged water and wastewater network damage may increase gastroenteritis exposure routes. In additioHPn, Escherichia coli (E.*coli*) and Non-Compliant Free Associated Chlorine (FAC-NC) have shown in the literature review to be associated as gastroenteritis agents.

3.2.1 DATA COLLECTION AND TYPE OF DATA

Data was sourced from both private and public institutions by requesting in writing. The study assumes the February 22, 2011 earthquake returned the existing damaged to a severe state following the September 4, 2010 earthquake in the study area. The study assumes there was no net migration change to the population (immigration is balanced by emigration). The study period extended from February 22, 2011 to March 28, 2011 (35 days) inclusive, and limited to those days because of data availability. The study was limited to those days because of data availability. All collected data was curtailed to reflect the 35 days. E.*coli* transgressions, FAC (non-compliant), gastroenteritis cases must have been sampled within that specific time frame. The study assumes that infrastructure repairs were a reflection of the damage that was caused by the February 22, 2011 earthquake. However, these repairs continued well after the time frame set for this study. Despite this, repairs that were logged after this time frame was included in the study because the repairs largely reflected the damage caused by the February 22, 2011 earthquake.

3.2.2 STUDY VARIABLES

The earthquake-induced infrastructure damage considered in this study were the water network pipe damage (which included both the main and submain pipes) and the wastewater network pipe damage. Liquefaction was represented as a percentage of Census Area Unit (CAU) that suffered liquefaction damage as lateral spreading and surface ejecta. There were two gastroenteritis agents considered: E.*coli* and FAC-NC. The factors considered in this research and their sources are outlined below. Descriptive details for each factor are provided in Appendix B.

Water Network Repairs

The study assumed the February 22, 2011 earthquake caused the water network damage (including the main and submain pipe) in Christchurch city. Damage in this context referred to pipe bursts. The data collated was repairs thereby implying that pipes were damaged in order to be repaired. Stronger Christchurch Infrastructure Rebuild Team (SCIRT) provided the data. The data set obtained verified the damaged pipes were in service, albeit at reduced service capacity.

Wastewater Pipe Repairs

The February 22, 2011 earthquake damaged the wastewater pipes that resulted in subsequent pipe repairs. The damage repairs were largely sewer mains, although other types of repairs were considered in the analysis such as pipe cracks. Thus, the repairs were taken as proof of damage. The data was obtained from SCIRT and showed the individual locations within the network that required repair.

Liquefaction Damage

Liquefaction damage was observed liquefaction of individual properties quantitatively categorised into the following: lateral spreading, ejected material, and graded according to the labels shown in Appendix C. It was assumed that earthquake characteristics—such as ground acceleration and shaking intensity—directly reflected the level of observed liquefaction. The data was collated from Tonkin & Taylor Limited. Henceforth in this study, lateral spreading and ejected material will be collectively termed liquefaction ground damage.

Escherichia *coli* Transgressions

The maximum acceptable value of E.*coli* in drinking water, for regularity purposes, is less than one E.*coli* count per 100mL (MOH, 2012a). E.*coli* transgression is the occurrence of E.*coli* that endanger water quality (MOH, 2008). A major transgression is considered when E.*coli* counts are greater than 10 per 100mL (MOH, 2012a). The water testing sampling teams from Canterbury District Health Board (CDHB) were sent out across the city to collect drinking water samples from street addresses, and commercial premises for E.*coli* testing across

Christchurch daily. This testing commenced two days after the February 22, 2011 earthquake and continued until mid-June 2011. Christchurch City Council (CCC) Laboratories and Canterbury Public Health (CPH) staff conducted this process (Dell, 2012). Data received from CPH comprised of E.*coli* transgression counts (MPN) per 100mL (Dell, 2012). Although host of heterogeneous mix of pathogens may have contributed to gastroenteritis, E.*coli* is the common indicator organism used to detect water contamination (Ball, 2006; BMJ, 2009).

Free Associated Chlorine or Free Available Chlorine

Free Associated Chlorine (FAC) was the residual chlorine available to disinfect the drinking water supply (MOH, 2008). According to the NZ's drinking water standards, the FAC concentration must be greater than 0.2mg/L. (MOH, 2012a). The data was collected from CDHB. Non-Compliant FAC (FAC-NC) is when FAC concentrations are less than 0.2 mg/L. FAC (>0.02mg/L) is used within the water network if the E.*coli* count is greater than 1-2 MPN/100mL (MOH, 2008). Presence of E.*coli* is often the indicative organism tested to verify contaminated water (MOH, 2008). This study considered that FAC-NC as a gastroenteritis agent because when FAC limits are non-compliant, there is the opportunity that gastroenteritis agents may remain in the drinking water supply.

Acute Gastroenteritis cases

Acute gastroenteritis cases were non-specific gastroenteritis cases reported by Institute of Environmental Science and Research Limited (ESR). The notification criteria to report acute gastroenteritis cases to ESR are outlined in (MOH, 2012b). The confirmed cases were aggregated per CAU over the 35 days following the February 22, 2011 earthquake. The recorded cases included basal levels of recorded gastroenteritis cases within the area.

Census Area Unit and Population

Christchurch population was included in the study using the 2006 NZ census data, the latest data set available at the time of data analysis (NZStatistics, 2012). The lowest common denominator to express population was a CAU where the boundaries were defined by NZ statistics (NZStatistics, 2012). There were 121 CAUs for the study area. The study presumed that the population from 2006 NZ census was representative of the Christchurch's population at the time of the February 22, 2011 earthquake. Further, the study assumed there was no overall change in population immigration or emigration in Christchurch after the September 4, 2010 earthquake.

3.2.3 DAMAGE PROFILE TABLE

A table, termed "damage profile table" amalgamated various data types that originated from different organisations into a single table, represented for each CAU. Thus, each row in the profile table represented a CAU with the corresponding columns referring to water damage, wastewater damage, liquefaction ground damage, E.*coli*, FAC-NC, and recorded gastroenteritis cases. There were 121 CAUs in the study area. Because the majority of data was spatial, ArcMap10.0 software was used to create the profile table using the spatial join operation to amalgamate the data. This meant, column data was aggregated per CAU, which converted point data into count data, because the spatial join operation "counts" the number of point data within a CAU boundary. Repeating this process for the 121 CAUs provided a "damage profile," for the study area whereby each CAU had a profile entailing damage counts of all factors. This profile table formed the basis for spatial analysis henceforth.

Recorded gastroenteritis cases were exempted from spatial join operation because the original data were aggregated per CAU. Liquefaction ground damage, however, required some pre-processing before undergoing spatial join operation. The raw data for liquefaction ground damage had irregular private land areas that were liquefied. Therefore, calculations were necessary to convert those separate areas into total percentage of liquefied area per CAU. This was achieved using the steps outlined below on ArcMap10.0:

1. Calculate liquefied areas with light orange to dark red categories in Appendix C.
2. Use spatial join to obtain total private liquefied areas per CAU.
3. Divide the total private liquefied area per CAU by total area of CAU and multiply by 100.

It is important to note that spatial join operation discards the magnitude of each factor outlined in Appendix C. For example, spatial join operation cannot discriminate to reflect intensity of repair damage in water and wastewater pipes; and show degree of E.*coli* or FAC-NC in each point data. For example, it cannot differentiate between 5MPN/mL and 8MPN/mL for E.*coli*.

3.2.4 DESCRIPTIVE ANALYSIS

Descriptive analysis consisted of two components: spatial and non-spatial analysis. Frequency distributions formed non-spatial analysis to address the spread of counted data per CAU using the profile table. In SPSS19 software, the frequency distribution tables and bar plots were created for each variable. The corresponding frequency distributions were categorised into deciles (10-quintiles).

Spatial analysis illustrated the frequency distributions by taking into account the geographical distributions using thematic maps in ArcMap10.0. The legends were classified using the natural breaks (Jenkins) classification system in ArcMap10.0 for the thematic maps. First, three thematic maps were produced using recorded gastroenteritis cases followed by thematic maps for other factors outlined in Appendix B. The first map compared gastroenteritis cases for the South Island (per CAU) over 35 days (22/2/2011–28/3/2011) following the February 22, 2011 earthquake. The second map concentrated in Christchurch by mapping recorded gastroenteritis cases before the earthquake (22/2/2010- 28/3/2010) and the third map after the earthquake (22/2/2011 –28/3/2011). These maps were created in ArcMap10.0.

3.2.5 SPATIAL STATISTICS

Spatial statistics took into account the effects of geographical variation at the lowest geographical unit, which was at CAU. The literature review identified three statistical tests that were carried out as part of spatial analysis. Namely, those were Moran's *I* (spatial autocorrelation), Hot Spot (HS) analysis and Besag–York–Mollié Model (BYM Model). The first two techniques used ArcMap10.0 while the latter method used WinBUGS14 software. All techniques assume the following from (Mitchell, 1999) :

- Null hypothesis states that no spatial patterns were exhibited
- Population within a CAU is uniformly distributed
- Any residuals created because of spatial analysis are normally distributed.

Collectively, Moran's *I* and HS evaluated the clustering effects of each variable whilst the BYM Model statistically analysed whether gastroenteritis point prevalence spatially explained water pipe damage (main and submain), wastewater pipe damage, liquefaction ground damage, E.*coli*, and FAC-NC.

3.2.6 GLOBAL MORAN'S *I*

Moran's *I* evaluated whether an exhibited pattern is clustered for a given set of features and its associated attributes (Fischer & Getis, 2010; Getis, 1992). Thus, Moran's *I* is a statistic that measures spatial autocorrelation (Getis, 1992). Moran's *I* statistic was evaluated using ArcMap10.0 software via spatial autocorrelation operation on ArcMap10.0, which incorporated the global Moran's *I* statistic calculations (ESRI, 2013). In particular, the spatial autocorrelation operation assumes that similar geographic features are placed closer to each other (Mitchell, 1999). Value of each CAU reflected the influence of neighbouring CAUs (Mitchell, 1999). The input data for Moran's *I* statistic was variables from Appendix B.

The outputs for Moran's *I* statistic using spatial autocorrelation in ArcMap10.0 was Moran's *I* index, z-score, p-value and the type of spatial pattern exhibited. Moran's *I* index is a value between -1 to 1(Mitchell, 1999). A value of Moran's *I* index less than zero indicate the spatial pattern is dispersed (CAUs with high and low counts are scattered) (Mitchell, 1999). A value equating to zero shows no apparent spatial pattern and a Moran I index greater than zero indicates the pattern is clustered (similar counts for CAUs are found together) (Mitchell, 1999). The z-score and p-values refer to the standard normal distribution. The z-scores are standard deviation. The p-value is the probability: probability the spatial pattern was created due to random process. Thus, a small p-value (small probability) indicates it is unlikely that the observed spatial pattern is due to any random process. Hence, very high or low z-scores are related to small p-values. The critical z-scores and p-values for probability confidence interval are shown in Appendix D. The spatial autocorrelation operation formed the stepping-stone to frame subsequent spatial statistics tools in order to analyse the potential clustering effects within Christchurch city.

3.2.7 HOT SPOT

The G-Ordi Gi statistic evaluated the location of statistically significant spatial clusters within a local area (Getis, 1992). The G-Ordi Gi statistic can identify local "pockets" of association that may not be found using the global Moran's *I* (Getis, 1992). The HS operation particularly suited the scale of the study area because CAU was considered at local level. The Hot Spot (HS) operation within ArcMap10.0 was used to evaluated the G-Ordi Gi statistic (ESRI, 2013; Getis, 1992). The HS operation was carried out for each factor outlined in Appendix B. The resultant was a thematic map with z-scoring and p-values. A high z-score reflected intense clustering of high counts (referred to as hot spots), whilst a low z-score meant clustering of low counts (cold spots).

3.2.8 SPEARMAN'S RHO

Spearman correlation coefficient, henceforth referred to as Spearman's rho (σ), was calculated for factors outlined in Appendix B using SPSS19. Although correlations do not necessitate causation, it can suggest how variables can interact, and are influenced by each other (Pallant, 2010). Spearman's rho is a type of non-parametric technique suited for count data. Identifying multicorrelation (high correlation among independent variables) is an important part of regression modelling.

3.2.9 BESAG–YORK–MOLLIÉ MODEL

The purpose of using a spatially explicit model is to understand whether there is spatial variation in gastroenteritis explained by factors considered in this research. Two mechanisms were considered. The first postulated that gastroenteritis point prevalence can be explained by damages to the water network, wastewater network, liquefaction ground damage (lateral spreading and surface ejecta) and gastroenteritis agents—FAC and E.*coli*. The second mechanism aimed to find out whether the recorded E.*coli* counts were spatially explained by damage from water, wastewater, liquefaction ground damage (lateral spreading and surface ejecta), and FAC-NC counts.

To investigate those two mechanisms, a Bayesian hierarchical conditional autoregressive model, Besag–York–Mollié (BYM) Model, that was first developed by Besag was applied (Besag, 1974, 1975, 1986; Besag, York, & Mollié, 1991). Since its publication, it has been adapted and used as a common platform for disease mapping and spatial regression, in particular to spatially quantify environmental area-specific factors; and incidence (García-Pérez et al., 2013; Manh et al., 2011; Saurina et al., 2010; Smith, Charlwood, Takken, Tanner, & Spiegelhalter, 1995). This adapted model may be viewed as a General Linear Regression Model (GLM) with an associated spatial component—Conditional Autoregressive Model (CAR)—which takes into account the geography of the study area (Besag et al., 1991). Henceforth this model, Besag–York–Mollié Model, will be referred to as the BYM Model.

To implement the BYM model, the WinBUGS14 software was used. The code to apply the model in WinBUGS14 was adapted from an example in the WinBUGS14 manual that explored the rates of lip cancer; initially studied by Clayton and Kaldor in 1987 as well as Bresow & Clayton in 1993 (Thomas, Best, Lunn, Arnold, & Spiegelhalter, 2004).

Using the adapted code, two models were considered. The respondent variables were gastroenteritis point prevalence (GAST-Model 1) and E.*coli* (ECM-Model 2), respectively. The covariates for Model 1 and Model 2 were selected factors from Table B-1; and outlined in Appendix B and F. Model 1 aimed to investigate if the recorded gastroenteritis point prevalence could be explained by the selected covariates; whilst, Model 2 asked the question: if the selected covariates spatially explained the observed E.*coli* count. The response variables (gastroenteritis point prevalence for Model 1 and E.*coli* for Model 2) in cell ί were assumed to follow a Poisson Distribution with mean, μ_i (Equation 4.0). The log of the mean was then modelled as a linear function of putative risk factors for each respective model (Equation 4.1, 4.2). This is a standard set-up for Poisson GLM (Thomas et al., 2004).

$$Y \approx_i \; Poisson \; (\mu_i) \tag{4.0}$$

$$\log \mu_i(GAST) = \log GAST + a0 + a1WSB_i + a2WSM_i + a3WW_i + a4FAC - NC_i + a5LIQ + a6Ec_i + E_i \tag{4.1}$$

$$\log \mu_i(ECM) = \log Ec_i + a0 + a1WSB_i + a2WSM_i + a3WW_i + a4FAC - NC_i + a5LIQ_i + E_i \tag{4.2}$$

Where: Y is the dependent variable, which in this study is gastroenteritis point prevalence (per CAU) for Model 1 and E.*coli* count (per CAU) for Model 2

(i) denotes observation for each CAU

Covariant coefficients were a0, a1, a2, a3, a4, a5, a6

GAST = the expected cases of gastroenteritis point prevalence using the population of the study area as the maximum number of people that can have gastroenteritis per CAU (Model 1)

ECM = the expected cases of E.*coli* using the population of the study area as the maximum number of people that can be exposed to E.*coli* per CAU (Model 2)

WSB = water submain pipe damage count per CAU

WSM = water main pipe damage count per CAU

WW = wastewater pipe damage count per CAU

FAC-NC = Free Associated Chlorine that is Non-Compliant (less than 0.2mg/L) count per CAU

Ec= E.*coli* count per CAU

LIQ = percentage of liquefied area per CAU

E = spatial residual for each CAU.

The residuals, E, is the discrepancy between the predicted and observed risk. The residuals were assumed to be spatially correlated as described in (Besag et al., 1991). The geographical spatial unit considered for this study was CAUs, and the study area map is shown in Figure A-1. Each CAU had a unique size and shape. To compensate for this irregularity population size was included in the analysis. Two CAUs were considered neighbours if one CAU shared a border with another CAU. To fully specify the BYM model, non-informative prior Gaussian Distributions were assigned to all parameters. This is a standard procedure when no prior information is available (Gelman, Carlin, Stern, & Rubin, 2003). Combining prior information with likelihood produced Posterior Distributions, which was used to produce the risk factor effect estimates the CAU estimates (posterior medians) as well as 95% credible interval (Gelman et al., 2003) for them. CAU specific residuals were also evaluated. The regression coefficients a1-a6 reflected the Estimated Effects (EEs) of the covariates on the respondent variables (Model 1 and Model 2). The above is further explained punctiliously by Lawson (2012), Lei et al. (2008), and Thomas et al. (2004).

The WinBUGS14 code is shown in Appendix E. A model was run for 10,000 iterations in total with 5000 burn-in (which means running the model without recording anything, because the convergence has not been reached yet) iterations with the remainder 5000 iterations for which output was recorded. Once convergence has been reached, the results do not fluctuate greatly. The convergence inspection was carried out by a visual check of the iteration history within the WinBUGS14 software.

Once the model has converged, the following outputs were recorded: Deviance Information Criterion (DIC), the predicted responses, covariate coefficients, and maps of expected counts; and residuals. DIC compares the complexity and “goodness of fit of data” of different models which is implemented in WinBUGS14 (Best, Richardson, & Thomson, 2005; Cowles, 2004). The lower the DIC, better the model. For any two models, 1-2 DIC difference was considered not very different, a 3-7 DIC change indicated suggestive difference whilst >7 DIC mean strong indifference (Best et al., 2005). Because DIC is sometimes unstable, it was recorded after 5000 iterations and then again, after 10000 iterations to make sure a model had converged.

The EEs of the regression-covariate coefficients were recorded and considered significant, if the 95% Bayesian Credible Interval (CI) excluded zero. The calculated expected counts or cases from the BYM Model for each dependent variable were mapped using ArcMap10.0. In addition, the residuals (E) for each CAU were recorded and mapped via ArcMap10.0. The Moran’s *I* was evaluated using ArcMap10.0 (otherwise known as spatial autocorrelation in ArcMap10.0) for residuals to check for spatial aggregation. Appendix F shows various covariates that were tried for Model 1 and Model 2. For each model, the DIC was calculated to see which of the model combinations (C1-C12) showed the best fit to the data.

3.3 QUALITATIVE ANALYSIS

The qualitative method involved interviewing volunteers at Emergency Centres (ECs) that were open to the public following the February 22, 2011 earthquake. This was the main source of data used to understand the successful mitigative steps that were undertaken to prevent gastroenteritis outbreaks within a welfare centre. The Figure 3-1 summarises the qualitative research method. The interviews were analysed adapting the GT approach described byCorbin and Strauss (2008). The qualitative analysis involved the following sections for interview analysis where the proceeding section is contingent on the previous.

3.3.1 QUESTIONNAIRE DESIGN

The literature review highlighted key overarching elements that were adaptable to different situations. Because of this reason, the literature review was used, albeit minimum to retain the essence of a GT approach. The questionnaire had the following major elements: sewerage facilities; rubbish disposal; health care; power and communication systems; drinking water; personnel hygiene; and preventative measures aimed to avert gastroenteritis incidences at ECs. The literature review highlighted the aforementioned overarching concepts. Additional elements included EC layout, operational times, staff and shift details, food preparation; and affiliated organisations. Each element had subsidiary questions. The questions on the major elements were open-ended to foster discussion from participants. Collectively, the questionnaire was organised into four major categories: welfare volunteer details, welfare operational services, essential lifeline services, and infection preventative measures with future recommendations. The questionnaire is included in Appendix G.

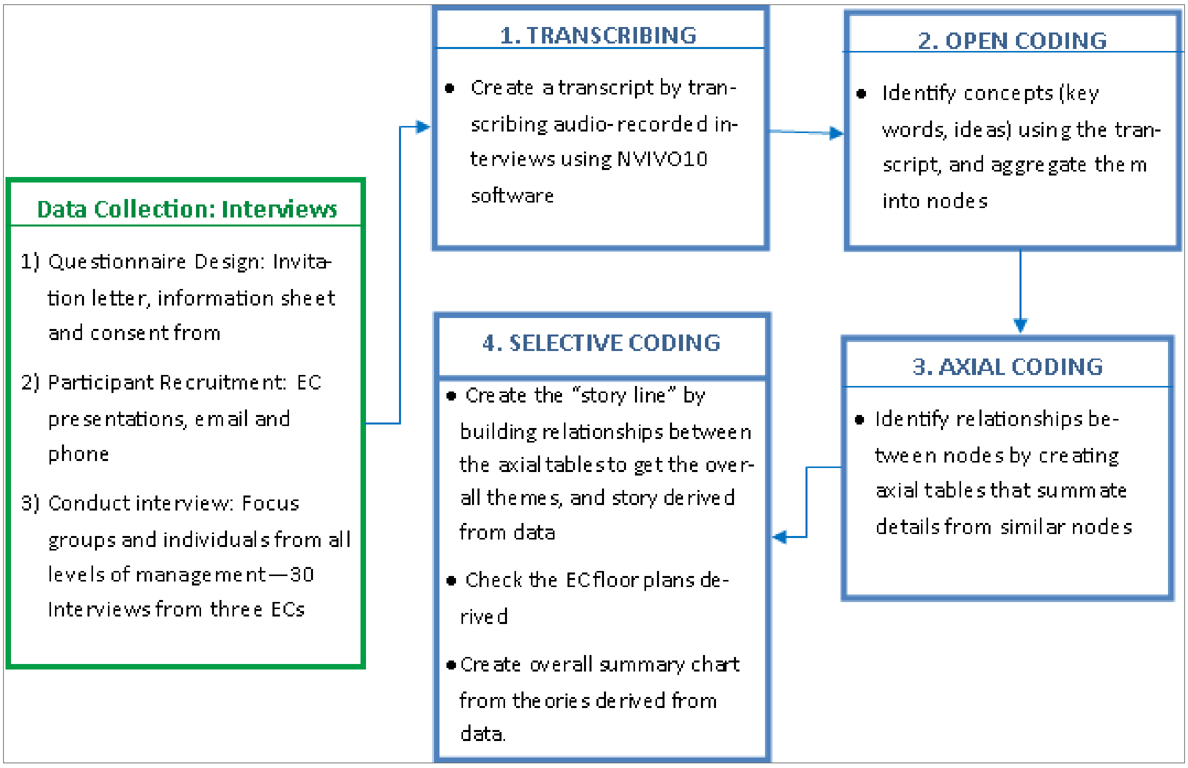

Figure 3-1: Represents the qualitative methods used in the study. The green boxes outlines the interview methods while the blue boxes shows the adapted grounded theory used to analyse the interviews. Abbreviation EC=Emergency Centre.

3.3.2 SUPPLEMENTARY DOCUMENTS

The questionnaire and its complimentary documents were reviewed by the Human Ethics Committee (HEC) at University of Canterbury and approval was granted to conduct the interviews as part of this research (HEC reference number: HEC 2012/161). The questionnaire included a participant invitation letter, participant information sheet, and a consent form:

- The invitation letter was an invitation to take part in the study along with other information such as interview length
- A participant information sheet provided the study's purpose, interview structure and participants' obligations; and how the results from the interview will contribute towards study objectives
- The consent form verified the participants' permission to conduct the interview, and that the participant understands the interview will be audio recorded
- The consent form had to be completed by the participant before commencing the interview.

3.3.3 RECRUITING PARTICIPANTS

Initially the investigator planned to interview 30 participants equally from Burnside High School EC (BEC), Linwood High School EC (LEC), and Cowles Stadium EC (CEC). However, due to time restrictions, there were 16 participants from BEC to represent the west side of Christchurch and collective 14 participants from CEC and LEC to portray the east side of Christchurch. The CEC and LEC participants were collectively grouped because those participants interchangeably refereed to both of the ECs throughout their interviews due to their experience.

It is important to note that as the interviews commenced, it became apparent that LEC was not open to the public after the February 22, 2011 earthquake because of liquefaction ground damage. This was not known prior to commencing the interviews; and, it was clear that information pertaining to LEC was important for the February 22, 2011 earthquake. However, LEC was included in the study, because it contained important information such as identifying themes as part of study analysis. The HEC at University of Canterbury granted approval to extend qualitative data collection by including LEC participants in the study. Thus, this study considered three ECs: two ECs after the February 22 2011 earthquake and one EC after the September 4, 2010 earthquake.

Participants were required from range of job roles and responsibility levels such as ground floor volunteers to upper management volunteers. Thus, list of potential candidates to participate in the interview was obtained from the EC manager, and the questionnaire package was emailed to everyone on the list, followed by a phone call a week later. In addition, the researcher presented at EC meetings and handed out the questionnaire packages to recruit participants. After the presentation, interested participants' contact details were collected to schedule an interview time. Questionnaire packages were emailed to other potential participants and followed-up with a phone call a week later. Participants were given the option of conducting the interview in small focus group style with up to five participants or an individual interview because of time constraints.

There was a single criterion for candidates to be able to take part in the study: participants must have volunteered (either in a volunteer or paid role) at one of the three ECs for the February 22, 2011 earthquake. It was mandatory for potential LEC participants must have volunteered at least once at LEC following the September 4, 2010 earthquake. There was no minimal time limit set for which a participant had to volunteer at an EC in order to take part in the interview. In doing so, it enabled the interviewer to seek participants with variety of job roles, whilst the

EC was open to the public. This in turn created a robust data collection. Thus, the study assumed, any additional factors—such as gender or age—were considered negligible, other than the criterion placed earlier.

3.3.4 CONDUCTING THE INTERVIEWS

Before conducting the interview, information in the invitation letter, information sheet and contents of the consent form were verbally explained (and given a hard copy of the documents) to all of the participants intending to take part in the interview. If participants wished to proceed with the interview, a consent form was completed and the interview commenced. As mentioned in the information sheet, the interviewed participants were given two weeks to sever their interview from the study. Part of the interview included annotating on a google printed map of the EC building about the EC layout. The interview was audio recorded which was supplemented with the interviewer taking notes throughout the interview. Participants had a copy of the questionnaire prior, and during the interview. As a result, participants had time to prepare for the interview beforehand, if they wished. After the interview, the interviewer gave some chocolate treats to all participants as a token of thanks. The one-off interviews were scheduled to last 30 minutes, but in most cases extended to one and half hours, especially for the focus groups.

3.3.5 ANALYSIS OF THE INTERVIEWS

As mentioned in the literature review, the interview analysis applied and adapted methods outlined by Corbin and Strauss (2008). First, the audio recordings were transcribed into text data by creating a transcript of each interview. This was followed by open coding, axial coding and selective coding before creating a "story line" that consolidates grouped concepts (identified during axial coding) to present as theories derived from interview data. The following sections describe open, axial, and selective coding.

3.3.6 TRANSCRIBING

The software NVIVO10 was used to transcribe the audio-recorded interviews. Each interview audio file was exported into NVIVO10, and segmented into three-minute intervals. From here, each audio segment was manually transcribed to create a synchronised transcript with the audio file. As a result, the transcript framed the basis for open, axial, and selective coding. Memos were written, within NVIVO10, and by hand throughout the analysis process. After transcribing, frequency counts of all the transcripts were carried out. It identified the most frequently used words (excluding definite, indefinite articles and prepositions) for the last part of the question within the questionnaire: protocols implemented that prevented a gastroenteritis outbreak at an EC (Appendix G).

3.3.7 OPEN CODING

Open coding involved listening to the audio recording whilst reading the transcript to identify similar concepts that can be grouped together. A concept was mostly considered, but not limited to repetitive or unique key words, ideas, sayings, or notions. Open coding was carried out to categorise similar concepts into nodes. A node was a range of attributes such as phrases, people, words, practical ideas that were carried out, and the EC itself. Nodes can be created within the same transcript or between different transcripts.

Open coding was carried out by listening to the audio whilst following the transcription. This enabled to let the interview data to speak for itself. Once a node was identified, information relating to that node was highlighted and categorised using NVIVO10. Moreover, listening to the audio recording whilst open coding checked the transcribing was carried out correctly.

It is important to note that parts of the audio recording referring to annotating the EC floor plans were not transcribed. Instead, part of the audio recordings detailing floor plans were "cut" (using a NVIVO 10 feature called clips) and coded into nodes using the direct audio recording. This was done because it was difficult to transcribe the material in the audio recording whilst participants were annotating.

3.3.8 AXIAL CODING

Building interconnecting relationships between established nodes formed the primary objective for conducting axial coding. It is important to note that Strauss and Corbin's (2008) information on axial coding was used as a guideline only. Nodes that were similar in content or ideas were amalgamated into a general node. The dissimilar nodes remained the same. A node (a general or a dissimilar node) was incisively summarised into a table termed Axial Table (AT) that contained information such as memos written and welfare centre details. Furthermore, ATs helped to identify conflicting answers and cross-referencing participants' answers because information pertaining to all ECs were visually represented.

The ATs were printed, laid on the ground, and rearranged repetitively by reading the material on the ATs. This continuous, yet iterative, interplay between nodes formed the foundation for establishing connections among isolated nodes. As a result, network of interconnected nodes were identified as well as chronological time line of activities for each EC. This created the platform for selective coding.

3.3.9 SELECTIVE CODING

Selective coding integrated and represented the established connections from axial coding into a framework and timelines for each EC—building the overall story line. In this study, this process was referred to as theory building. The framework, which was expressed as a flow chart showed how each element interacted with another in a hierarchical manner. Deriving this chart was an iterative process. The framework chart encompassed all the components that interacted together to prevent a gastroenteritis outbreak at ECs. Putting the interconnected events into a chronological order created the timeline. Additional notes were also summarised for each EC. The EC layouts were also refined by digitising the original EC maps. Checks were conducted to inspect for any gaps in the framework, timelines, EC layouts, and summary notes. The first check was using the aforementioned resources to answer the questions in questionnaire. Whilst the GT approach cannot corroborate or disprove the theory generated from the data, it is important to establish that sufficient information has been collated to answer the research questions adequately (Glaser, 1998). Any questions that could not be answered in the questionnaire highlighted areas for further investigations or rechecking the original data for errors. The second and final check was to return to some of the senior participants to check whether the final EC layouts generated were correct. This was needed because collating annotated diagrams from each interview may have led to incorrect information.

3.4 METHODOLOGY SUMMARY

- This chapter described two overarching methods used in the study using the February 22, 2011 earthquake: quantitative and qualitative
- The quantitative methods used to understand spatial association between recorded gastroenteritis cases and its associated factors
- The quantitative method commenced with creating a damage profile table, which amalgamated the factors considered in this research per CAU
- Range of methods was described for quantitative analysis that included the following tests: frequency distributions, thematic maps, Spearman's Rho, Moran's *I*, Hot Spot analysis, and the Besag–York–Mollié Model
- The aim of the qualitative methods was to investigate the protocols implemented at ECs that prevented gastroenteritis outbreak following the February 22, 2011 earthquake
- Qualitative analysis involved designing a questionnaire and conducting interviews for 30 participants from three ECs
- An adapted GT from Corbin and Strauss (2008) was applied to analyse the interviews

- The major components of the interview analysis were transcribing, open coding, axial coding and selective coding.

Collectively quantitative and qualitative methods describe mechanisms to assess and prevent gastroenteritis outbreaks in a post-earthquake setting.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

Chapter four presents the results of the quantitative and qualitative methods. Quantitative results begin with illustrating the gastroenteritis prevalence in Christchurch after the Canterbury Earthquakes. Followed by outlining the spatial association of factors described in Table B1 to B3 using the following tests and techniques: thematic maps, frequency distributions and Spearmen's rho (σ), Moran's *I*, Hot Spot (HS) and the Bayesian Hierarchical Conditional Autoregressive Model—the BYM Model. Given the presence of gastroenteritis risk factors, the qualitative technique—Grounded Theory (GT)—outlined the mitigative practices that were carried out to prevent a gastroenteritis outbreak at an Emergency Centre (EC).

4.2 QUANTITATIVE RESULTS

4.2.1 GASTROENTERITIS POINT PREVALENCE

Two gastroenteritis clusters were identified by mapping the gastroenteritis point prevalence (per CAU) over the South Island: Christchurch and Invercargill (Figure 4-1). Christchurch city showed the largest cluster of gastroenteritis cases recorded over the 35 days (22-02-2011 to 28-04-2011). The red square in Figure 4-1showed that 91% of gastroenteritis point prevalence was in Christchurch. Moreover, Figure 4-2 illustrates a 14-fold increase in recorded gastroenteritis point prevalence over Christchurch city as a whole by comparing recorded gastroenteritis point prevalence (per CAU) for 35 days before the earthquake (22-02-2010 to 28-04-2010) and after the earthquake (22-02-2011 to 28-04-2011)[1].

4.2.2 FREQUENCY DISTRIBUTIONS AND SPEARMAN COEFFICIENT CORRELATIONS

All frequency distributions produced similar power-law graphs for factors in Table B1-3: large frequency of low damage counts with small frequency of high damage counts per CAU. The frequency distributions are shown in Figure H-1.

[1] The 2010 data included only gastroenteritis cases as defined by Ministry of Health Communicable disease definitions by contract, the 2011 database included *all* enteric disease cases. Moreover, GPs in Christchurch had been alerted to the importance of notifying enteric disease, so there was an increase in reporting of such cases outside the normal reporting criteria, which led to the 14-fold increase in gastroenteritis cases. The student was not aware of this information prior to the completion of her thesis, and neither her supervisors were made aware of these methodological constraints. This finding does not negate the results of the thesis study itself, of which, the main aims were to identify any possible correlation between gastroenteritis cases with the earthquake-induced infrastructure damage, liquefaction ejecta on the ground, and the presence of gastroenteritis agents in the potable water along with mitigative factors that were carried to prevent gastroenteritis outbreaks at emergency centres.

The Spearman Rho (σ) shown on the original column-matrix format is provided in Appendix I. The Figure 4-3 shows the summarised matrix of Spearman's Rho, which identified three levels of associations: high, medium and low. All Spearman's Rho were significantly different from 0 at $p<0.01$. The summary matrix followed the lower diagram on Figure 4-3, which generalised the three association levels. It follows that there is a high association between infrastructure damages (LIQ, WW, WSM, and WSB). A medium-level association between those collective infrastructure damages and FAC-NC, and a low-level association between GAST; and expected count of E.*coli*. In turn, GAST had a low-level associated with expected count of E.*coli* and collective infrastructure damages. In addition, there is also a medium-level association between LIQ and WSB.

4.2.3 THEMATIC MAPS

Thematic maps in Figure 4-4 and 4-5 shows the geographical distribution of damage counts for factors described in Table B1-3. The maps demonstrate that areas with high damage counts (with low frequency shown via frequency distributions) were aggregated together. This is shown by a highlighted area, a brown outlined in Figure 4-4 and 4-5. However, E.*coli* count did not display this highlighted area and visually looked interspersed, Figure 4-4A.

No single CAU had the highest damage category for all of the factors, but heterogeneous mix of high damages were illustrated by the aggregated zone for eastern suburbs. They included Aranui, Avondale, Bexley, Chisnall, Ensors, Rawhiti, Linwood East, Linwood North and South Brighton (Figure 4-4 and Figure 4-5). However, Avondale had the highest categories of water (main and submain) network damage, wastewater network damage, and liquefaction ground damage. South Brighton showed the single CAU with the highest count categories E.*coli,* FAC-NC, and gastroenteritis point prevalence (Figure 4-4). For example, New Brighton area fell into the high damage category for all of the factors—with the exception of wastewater damage.

4.2.4 SPATIAL AUTOCORRELATION

For this study, for all factors, the Moran's *I* index was positive. Because of the high z-score signifies statistical significance, the spatial pattern was classed as clustered (Table J-1). Notably, E.*coli* and gastroenteritis point prevalence had the lowest Moran's *I* index 0.015 and 0.05, respectively. The results are shown on Table J-1. Clustering of the factors was statistically significant at 1% level (because of the z-scores greater than 2.58) and at 5% significant level since the z-score range was 1.96-2.58 (Figure D-1).

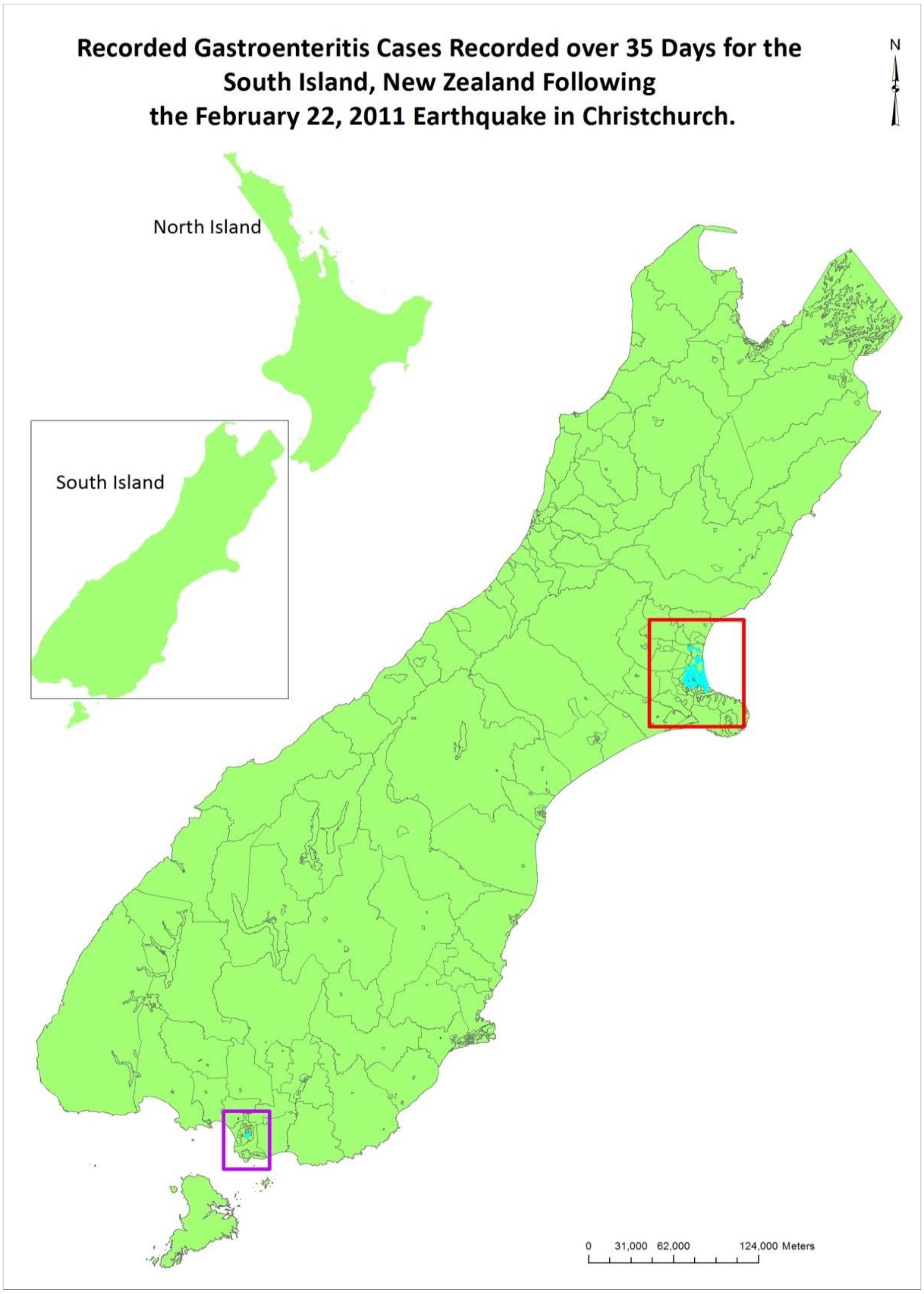

Figure 4-1: Gastroenteritis cases for South Island, New Zealand (NZ) between 22/2/2011 – 28/3/2011 (35 days). The left hand side map shows NZ map with the study area outlined in a black square. The centre map shows South Island with gastroenteritis cases (aggregated per Census Area Unit [CAU]) highlighted in blue. The purple square represents the small cluster within Invercargill city whilst the red square shows the larger cluster in Christchurch City.

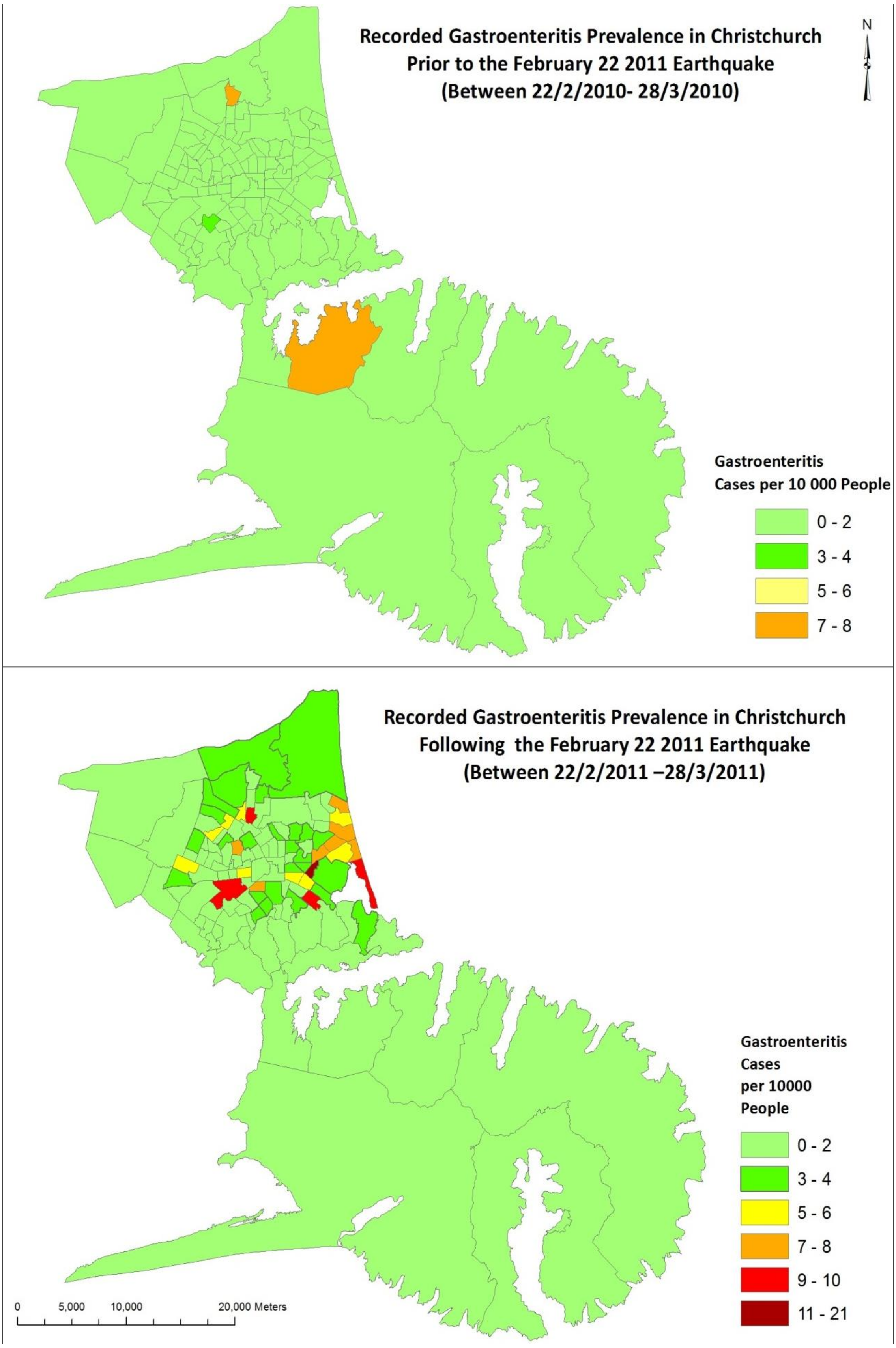

Figure 4-2: Gastroenteritis cases in Christchurch after the February 22, 2011 earthquake. The above map shows recorded gastroenteritis cases recorded from 22-02-2010 to 28-03-2010 whilst the bottom map displays gastroenteritis cases from 22-02-2011 to 28-03-2011.

4.2.5 HOT SPOT ANALYSIS

The Hot Spot (HS) operation, which was built into ArcMap 10.0, produced thematic maps that illustrated CAUs with high and low damage counts that were statistically significant. The high and low damage counts, referred to as hot and cold spots respectively are shown in Figures 4-6 and 4-7. In both of the figures (Figure 4-6 and 4-7), HSs were categorised into the orange-red shades whilst a cold spot was shown by the blue shades. Neither figures showed cold spots.

South Brighton was the common HS for E.*coli*, FAC-NC, gastroenteritis cases and main water pipe damage (per 10,000 people)—Figure 4-6. New Brighton was the single overlapping CAU between Figures 4-6 to 4-7. Some CAUs had interspersed HSs towards the central to west side of Christchurch (such as Addington, Belfast South, Bryndwr, and Northcote). Contrastingly, Figure 4-7 showed HSs aggregated in similar CAU across the four maps. Bexley was the common CAU amongst water (main and submain pipes), wastewater, and liquefaction ground damage amongst HSs (Figure 4-7). It is also important to mention there were some isolated CAUs with HSs scattered (Figure 4-6 and 4-7). Interestingly, HSs in the FAC-NC map (Figure 4-6B) corresponded to HSs shown on the water (main and submain pipes) and wastewater maps in Figure 4-7A, B and D.

	Ec = E. *coli* count in drinking water supply (MPN/100mL) per CAU.	**FAC** = Free Associated Chlorine that is Non-Compliant (<0.02mg/L) count per CAU.	**GAST** = Gastroenteritis cases between 22/2/2011-28/3/2011 per 10,000 people per CAU.	**WSM**= Water network damage from main pipes per CAU.	**WSB** = Water network damage from sub-main Pipes per CAU.	**WW**= Wastewater network pipe damage per CAU.
LIQ= Percentage of area of CAUs that were liquefied	0.294**	0.620**	0.254**	0.817**	0.676**	0.817**
WW= Wastewater pipe damage count	0.256**	0.732**	0.233**	0.788**	0.842**	1.00
WSM= Water damage from main pipes	0.339**	0.697**	0.233**	1.00	0.782**	0.788**
WSB= Water damage from submain Pipes	0.293**	0.730**	0.250**	0.782**	1.00	0.782**
Ec= E. *coli* count in drinking water supply (MPN/100mL) per CAU.	1.00	0.386**	0.143	0.339**	0.293**	0.256**

** Correlation is significant at 0.01 level

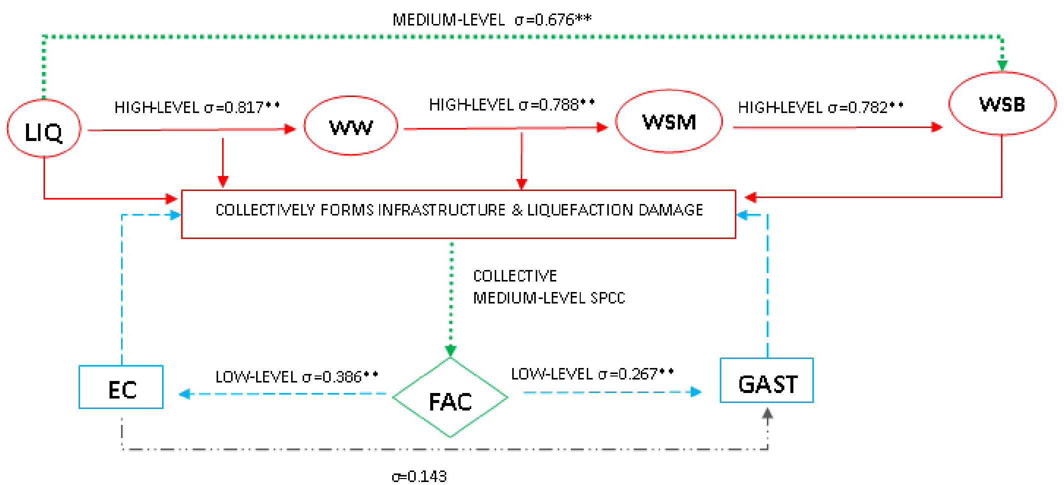

Figure 4-3: Spearman's Rho (σ) associations between various factors that were recorded after the February 22, 2011 earthquake. The table corresponds to the relevant Spearman's Rho associations and their category levels. There were three significant Spearman's Rho levels identified: low, medium and high. The low association level is blue coloured boxes with dashed arrows. The medium-level is depicted by green the coloured-diamond shape accompanied by the dotted-arrows. The red circles and solid-line arrows reflect a high Spearman's Rho. The black double-dashed line shows statistically non-significant SPCC correlation. All infrastructure (WW, WSM & WSB) and LIQ is collectively named "infrastructure and liquefaction damage" platform for easy navigation. Percentage of liquefied areas is the liquefaction ground damage due to lateral spreading and surface ejecta.

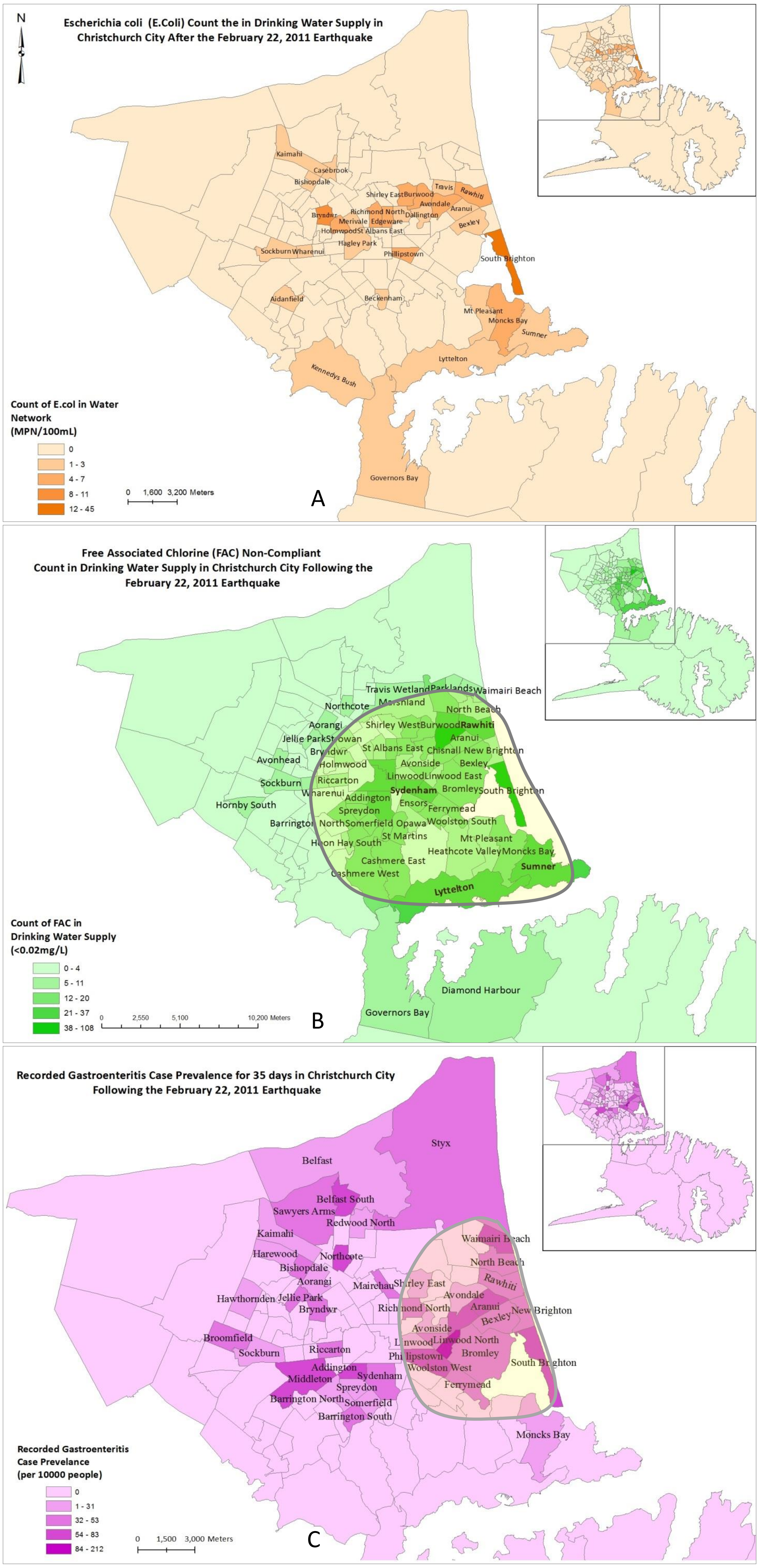

Figure 4-4: Thematic maps for aggregated Escherichia *coli* (E.*coli*) in map A; Free Associated Chlorine Non-Compliant (FAC-NC) in map B; and recorded gastroenteritis point prevalence following the February 22, 2011 earthquake. The yellow shape overlaying FAC-NC map shows the aggregated areas with high counts of FAC-NC. The gastroenteritis cases were recorded over 35 from February 22, 2011.

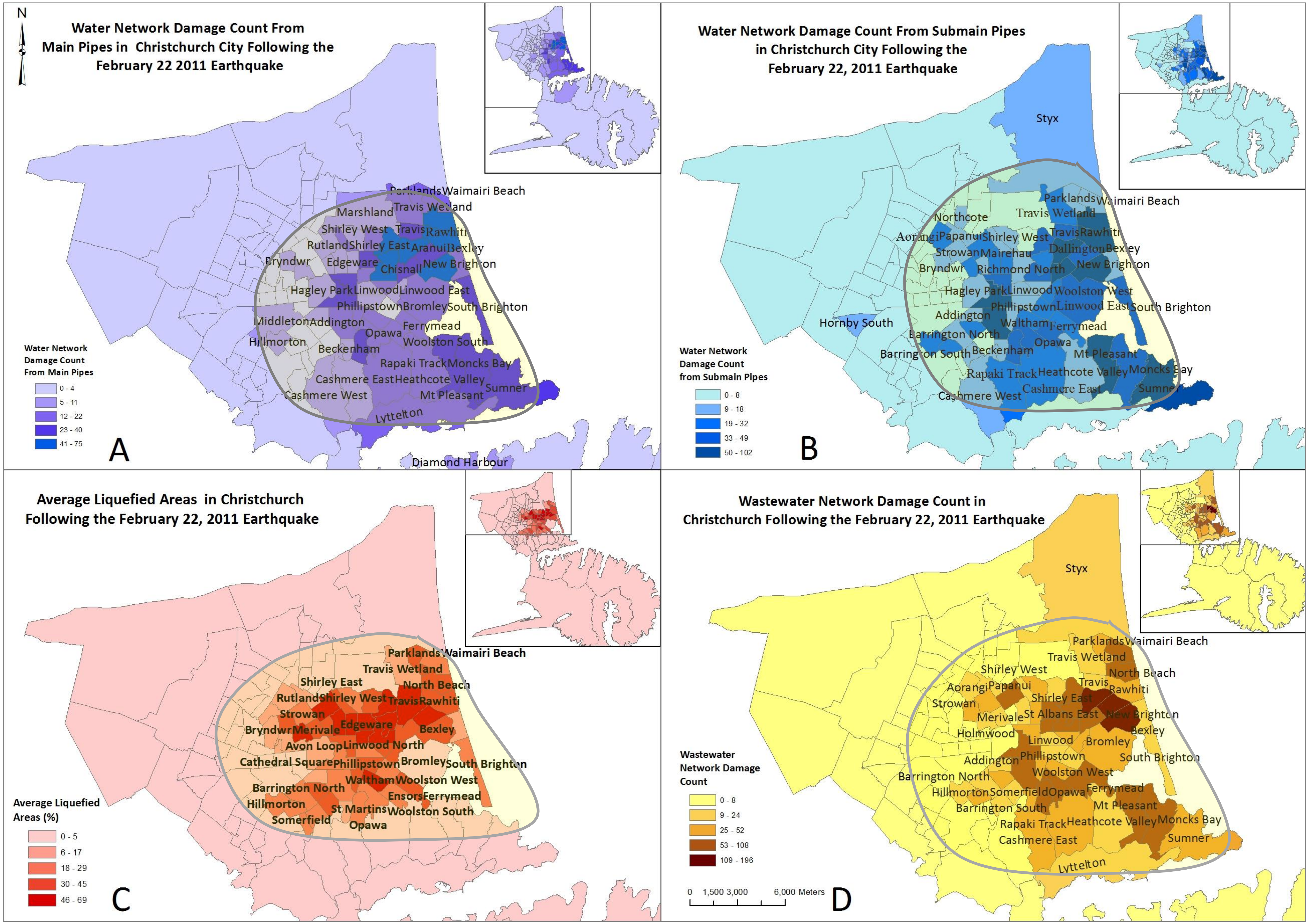

Figure 4-5: Illustrates infrastructure and liquefaction damages that are aggregated into each Census Unit Area (CAU) after the February 22, 2011 earthquake. Liquefied areas are ground damage due to lateral spreading and surface ejecta.

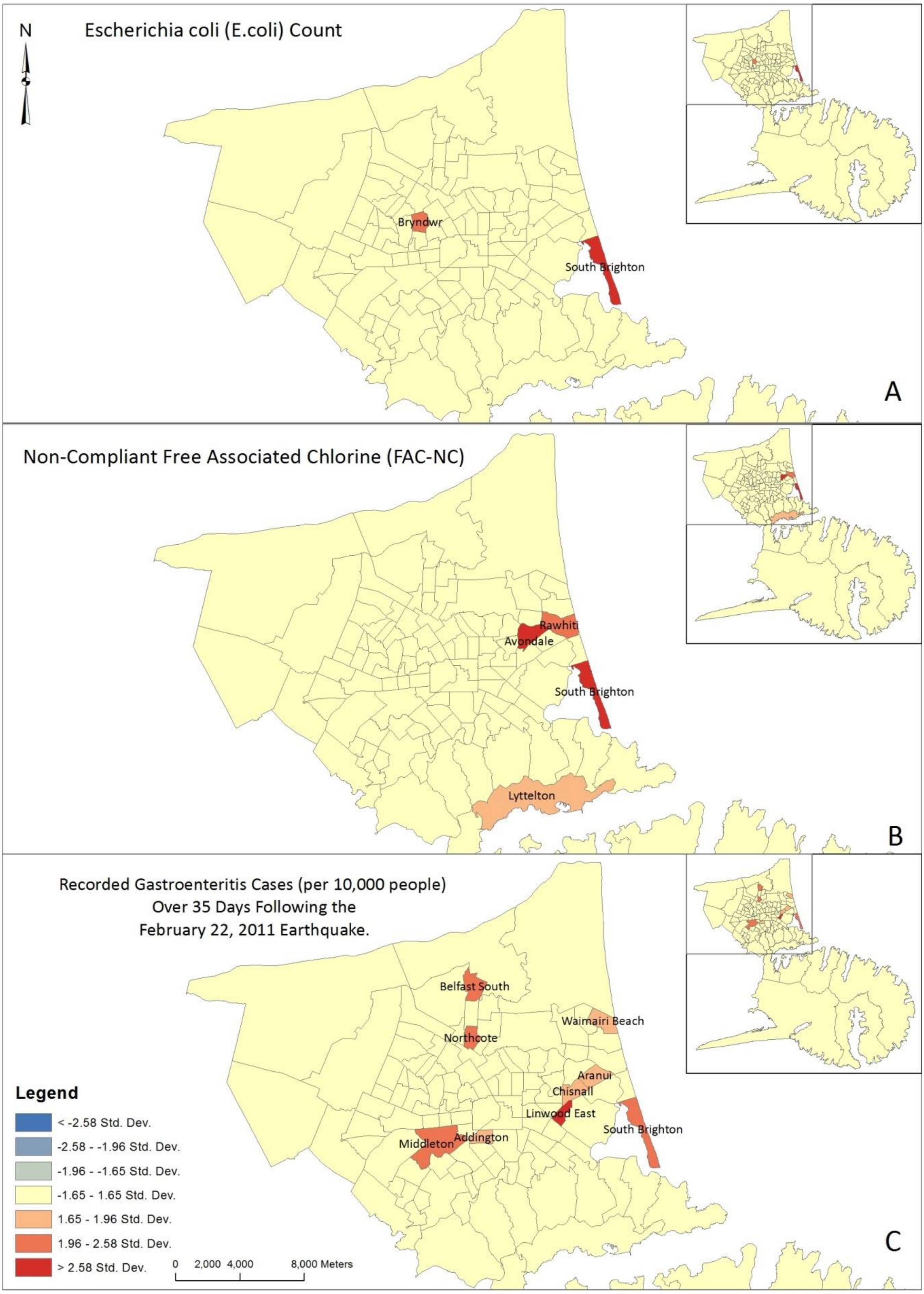

Figure 4-6: Hot Spot (HS) results for gastroenteritis- factors following the February 22, 2011 earthquake in Christchurch. The yellow shade indicates no clustering, whilst the red and blue shades indicate hot and cool spots, respectively. The hot spots are high values that are clustered together with statistical significance (orange-red shades). Cold spots show areas statistically significant low values that are clustered together (blue shades). Escherichia coli is referred to as *E.coli.*

Figure 4-7: Hot Spot (HS) results for infrastructure and earthquake factors following the February 22, 2011 earthquake in Christchurch. The yellow shade indicates no clustering, whilst red and blue shades indicate hot and cold spots, respectively. The hot spots are high values that are clustered together with statistical significance (orange-red shades). Cold spots (blue shades) show areas statistically significant low values that are clustered together. There are aggregated spatial locations of HSs for each map whereas water network damages showing to aggregated areas of HSs. Liquefaction is ground damage due to lateral spreading and surface ejecta.

4.2.6 SPATIAL ANALYSIS: BAYESIAN HIERARCHICAL CONDITIONAL AUTOREGRESSIVE MODELLING

The Besag–York–Mollié Model was used in the WinBUGS14 software and was run to test two associations: the first to understand whether the gastroenteritis cases spatial distribution was explained by liquefaction ground damage (lateral spread and surface ejecta), FAC-NC, and infrastructure damage. The second, if E.*coli* counts may have acted as a gastroenteritis agent due to liquefaction ground damage and infrastructure damage. The BYM models were combined with ArcMap10.0 analysis, which produced the following outputs: DIC, model coefficients, expected counts for model combinations, and corresponding residual maps. The residual maps were then used test for spatial autocorrelation using ArcMap10.0. The original data tables summarising the recorded inputs are shown in Table B-1to B-3.

According to DIC the best factor combination (the lowest DIC) for Model 1 was E.*coli* (C2 with DIC=202.4). That is, E.coli data best "fitted" the recorded gastroenteritis cases. For Model 2, the best factor combination (with DIC of 208.9, as shown in Table 4-1) was C11. Thus, combination of water damage (main and submain pipes), wastewater and liquefaction data best fitted the E.coli data. In Model 2 there was minimal DIC difference between different factor combinations (less than 1-2 range set at the outset). Because of this, the second best factor combination was considered for further analysis in Model 2— C9. This means the combination of water (main and submain pipes), liquefaction and FAC-NC, may have explained the recorded E.*coli* counts. These factor combinations— C2, C9, C11—had the lowest DIC, which meant they were the only factor combinations considered for further analysis.

4.2.6.1 MODEL COEFFICIENTS

The raw coefficients from each model were converted into an Estimated Effect (EE), which is summarised in Table 4-1. The EEs, an important output of the BYM Model shows the effect of covariates on a factor combination. The EEs were considered statistically significant if the 95% Credible Interval (CI) excluded zero. In Model 1, C2 showed all statistically non-significant EEs. In contrast, Model 2 produced statistically significant EEs. In the C11 combination, liquefaction ground damage was a statistically significant EE (Table 4-1). It means that a single liquefaction ground damage unit (1% of the total CAU area) is associated with an increase of E.*coli* count (MPN/100ml) in drinking water supply by 5%, per CAU (Table 4-1). Likewise, C9 (with the second lowest DIC for Model 2) had two factors that were statistically significant—FAC-NC and LIQ (Table 4-1). Thus, for every unit increase of FAC-NC (per MPN/100ml), the E.*coli* count in drinking water supply increases by 6%, per CAU. Liquefaction ground damage had the same EE as C9 (Table 4-1). Comparing EEs from both of the models shows water submain pipe damage tend to be negatively associated with risk of gastroenteritis and E.*coli* because of the negative EEs. For all the factor combinations the EE for a1 was negative (Table 4-1). For example, the C9 combination's EEs for WSB was -3%.

4.2.6.2 WINBUGS14 MAPS

The expected count maps produced by WinBUGS14 using the BYM model is shown in Figure 4-8. The expected counts for all the three factor combinations were low for the overall study areas, except for eastern suburbs in Christchurch (Figure 4-8A, C, and E). The residual maps from Figure 4-8 shows the discrepancy between the expected and the observed counts (or cases) for a dependent variable within factor combination. An overestimated residual is when the expected counts that were calculated in the BYM Model were much higher than the observed counts from the input data. An underestimated residual is the opposite; the expected counts (or cases), which is lower than observed counts from the input data. Both overestimated and underestimated residuals represent the discrepancy between the expected counts that were calculated in BYM Model. The underestimated residuals are shown in blue shades while the overestimated residuals are represented by red-orange shades (Figure 4-8). The green shades show areas with minimal residuals in Figure 4-8 (minimal discrepancy between the calculated expected counts and the observed counts from input data).

In Model 1, the residual map (Figure 4-8B) shows the least range of residual discrepancy, yet the DIC was much higher, indicating poor data fit. The residuals from Model 2 show two combinations—C9, C11—with the range of overestimated and underestimated residuals (Figure 4-8D, F). The C11 residual map (Figure 4-8F) had the largest ambit of residuals in spite of the lowest DIC amongst Model 2 factor combinations (Table 4-1). Furthermore, Moran's *I* statistics (using the spatial autocorrelation operation in ArcMap10.0) verifies that the all residuals maps were statistically clustered, as shown on Table K-1, so that CAUs showing underestimated, overestimated and minimal residuals were statistically aggregated.

Table 4-1: WinBUGS14 results for two dependent variables: gastroenteritis cases and Escherichia coli (E.*coli*) counts with respective factor combinations. Lower the DIC, better the model fit. Positive coefficient indicates increases in likelihood; a negative coefficient has the opposite effect. The abbreviations included in the table are a (0, 1, 2, 3, 4, 5, 6) =denote coefficients considered in the model, CI= Credible Interval, Ec= Excpected Count of E.*coli*, WSB=Water submain pipe damage count, WSM = Water main pipe damage, WW= Wastewater damage count, L= Liquefaction ground damage (lateral spread and surface ejecta) per CAU in percentage, FAC-NC= Non-Compliant Free Associated Chlorine (0.02mg/L). All data counted per Census Area Unit (CAU).

Combination Number	Coefficient label	Estimated Effect (EE)(%)	Confident Interval (2.5%,97.5%)	DIC
Model 1				**DIC10000**
C1:W+WW	a1=WSB	0.5	(-2,3)	212.7
	a2=WSM	0.1	(-4,0.1)	
	a3=WW	0.3	(-0.6,1)	
C2: Ec	a6=EC	2.7	(-3,8)	202.4
C3: FAC-NC +Ec	a4=FAC-NC	1.5	(-2,4)	210.2
	a6=EC	-0.5	(-8,7)	
C4 :W+WW+Ec	a1=WSB	1.0	(-2,4)	209.8
	a2=WSM	-1.2	(-5,2)	
	a3=WW	0.4	(-1,1)	
	a6=EC	3.1	(-3,8)	
C5:W+WW+FAC-NC +L+Ec	a1=WSB	0.7	(-2,4)	214.0
	a2=WSM	-0.9	(-5,3)	
	a3=WW	0.3	(-1,1)	
	a4=FAC-NC	0.6	(-3,4)	
	a5=LIQ	0.2	(-2,2)	
	a6=EC	1.8	(-7,11)	
Model 2				**DIC5000**
C6: W+WW	a1=WSB	-4	(-9,1)	210.1
	a2=WSM	9	(2,13)	
	a3=WW	0	(-2,2)	
C7: W+L	a1=WSB	-2	(-9,3)	209.8
	a2=WSM	4	(-1,16)	
	a5=LIQ	5	(1,9)	
C8: W+FAC-NC	a1=WSB	-3	(-7,3)	209.9
	a2=WSM	5	(-3, 12)	
	a4=FAC-NC	7	(2,9)	
C9: W+L+FAC-NC	a1=WSB	-3	(-7,1)	209.3
	a2=WSM	4	(-3,10)	
	a4=FAC-NC	6	(2,9)	
	a5=LIQ	5	(1,8)	
C10: W+WW+FAC-NC	a1=WSB	-3	(-8,3)	209.4
	a2=WSM	4	(-3,12)	
	a3=WW	0	(-2,2)	
	a4=FAC-NC	7	(3,11)	
C11: W+WW+L	a1=WSB	-1	(-7,3)	208.9
	a2=WSM	5	(-0.3,11)	
	a3=WW	-1	(-2,1)	
	a5=LIQ	5	(1,9)	
C12: W+WW+FAC-NC+L	a1=WSB	-3	(-7,2)	209.6
	a2=WSM	5	(-2,11)	
	a3=WW	0	(-2,1)	
	a4=FAC-NC	6	(4,9)	
	a5=LIQ	4	(1,7)	

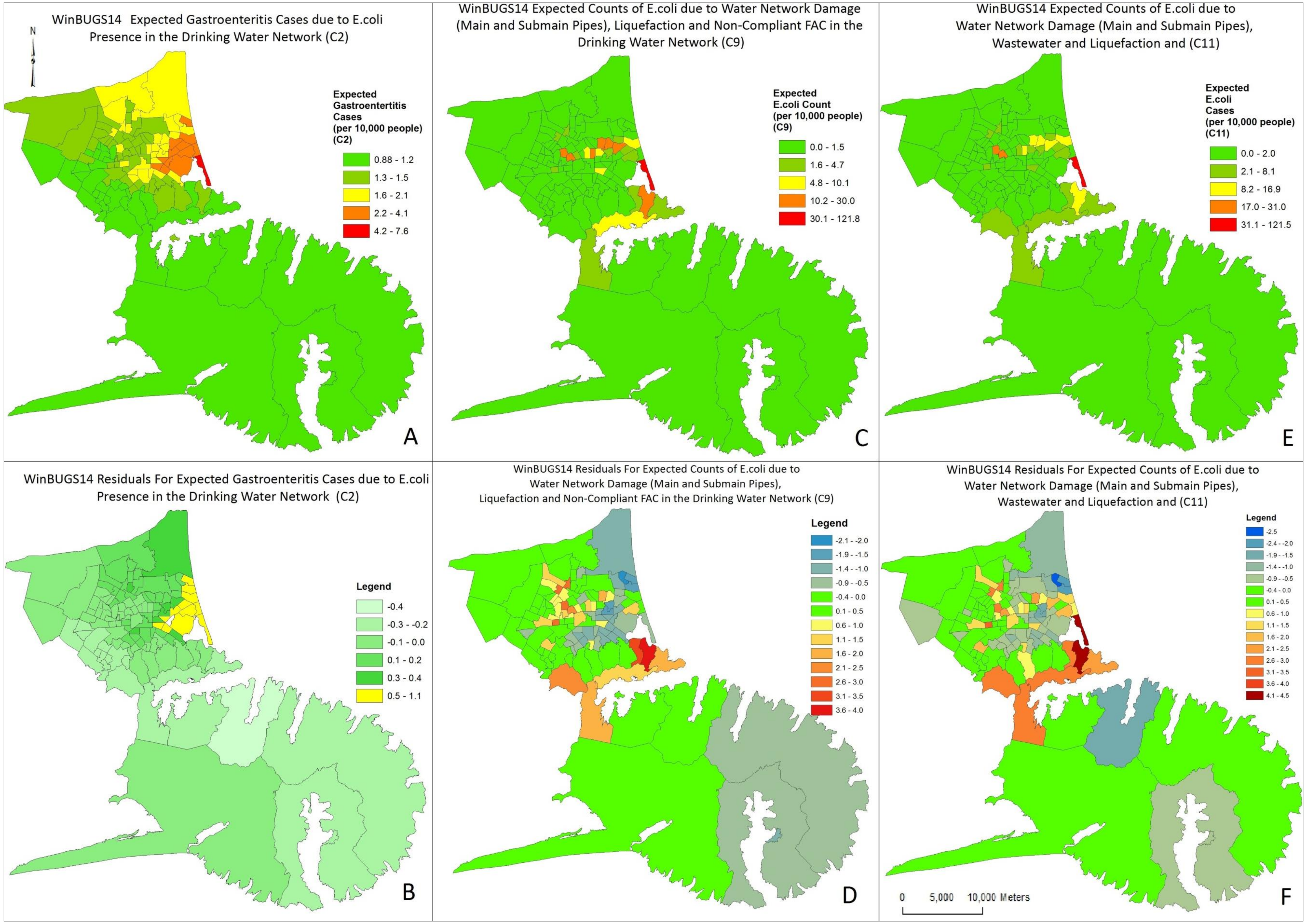

Figure 4-8: WinBUGS14 risk and residual maps. Figures A, B, and C represent the risk map for various factors while B, D, F shows the corresponding residual maps, respectively. The residual indicate area that the considered factors did not explain the observed response variable (recorded gastroenteritis point prevalence for Model 1 and Escherichia (E. E.*coli*). An overestimated residual is when the expected counts are higher than the observed counts from the input data. An underestimated residual is the opposite; the expected counts (or cases) are lower than observed counts from the input data. The underestimated residuals are shown in blue shades while the overestimated resid uals are represented by red-orange shades. The greed shades represent areas with minimal discrepancy.

4.3 QUALITATIVE RESULTS

4.3.1 EARTHQUAKE DAMAGE SURROUNDING THE EMERGENCY CENTRES

Given the infrastructure damages shown in the quantitative analysis, the purpose of qualitative data analysis was to identify the successful mitigations that were carried out to prevent gastroenteritis outbreaks at an Emergency Centre (EC). An EC is represented by an area called a Ward. A ward, for electoral reasons, is a division of territorial authorities (NZStatistics, 2012) Hence, there is an emergency centre representing an ward. The location and management of an EC is maintained by often, but not limited to, volunteers pertaining to its corresponding ward. For this reason, the earthquake factors from Table B1 to 3 are displayed per ward in Figures 4-9 to 4-10. Both Cowles Emergency Centre (CEC) and Linwood Emergency Centre (LEC) pertained to Hagley-Ferrymead Ward whilst Burnside Emergency Centre (BEC) was under the Fendalton-Waimairi Ward.

Table 4-2, summated the people that may have been exposed to the earthquake-induced infrastructure damage and gastroenteritis agents. Consider, the BEC ward area, which was 65% larger with 27% more residents housed compared to CEC. However, CEC ward suffered 89% more liquefaction ground damage (lateral spread and surface ejecta); 67% more wastewater network pipe damage; 56% more water main pipe and 50% more water submain pipe damage. Likewise, CEC ward had more gastroenteritis cases and its agents: 56% more FAC-NC counts and 49% gastroenteritis point prevalence compared to BEC (Table 4-2). However, CEC had 67% less E.*coli* counts compared to the BEC ward. Moreover, it is evident from Table 4-2, Figures 4-9 and 4-10 that east side of Christchurch sustained high earthquake-induced infrastructure damages (Figure 4-10); liquefaction ground damage; gastroenteritis cases; and one of its agents (FAC-NC). The west side of Christchurch had overall minimal damage, except with high E.*coli* count. Because of this reason, CEC was chosen to represent east side whilst BEC represented the west side of Christchurch. LEC was open following the September 4, 2010 earthquake. The data for Table 4-2 was garnered following the February 22, 2011 earthquake. Therefore, LEC was not included in data summary for Table 4-2. Reasons for including LEC are outlined in section 4.4.

4.3.2 EMERGENCY CENTRE OBJECTIVE AND COMPONENTS

The main purpose of an EC in February 22, 2011 was to provide temporary relief for "2-3 days" for people who were destitute because of the earthquake. The operational hierarchal structure of an EC is shown in Figure L-1. The ECs operates collaboratively with the Christchurch City Council (CCC) liaison officer to oversee required operations to maintain an

EC. The lower tiers operate on welfare aspects (WSTL) whist SSTL maintains technical aspects of the EC. The WSTL is responsible to maintain the EC layout; look after evacuees and social services; EC resources are utilised appropriately; and feedback information on welfare issues to support section, especially if any further resources are required. The purpose of support section is to provide technical aspects such as stock take for incoming resources, and maintaining communications with Emergency Operation Centre (EOC)—regional emergency coordinating centre—and submit situation reports.

A situation report, otherwise known as a sit report, is a document signed by the ECS, that updates the EOC summarising an EC status: the number of evacuees presently; resources available like food and water bottles; social services available; staff housed; any particular issues; and resources required by the EC. It is a “snap-shot” of the EC operations at the time. The EOC depicts how often a sit report is lodged, which in all three ECs were every 2 hours. Resources required by the EC must be sent to EOC using a sit report. Collectively, the welfare and support sections cater to provide the essential necessities for evacuees on a temporary basis.

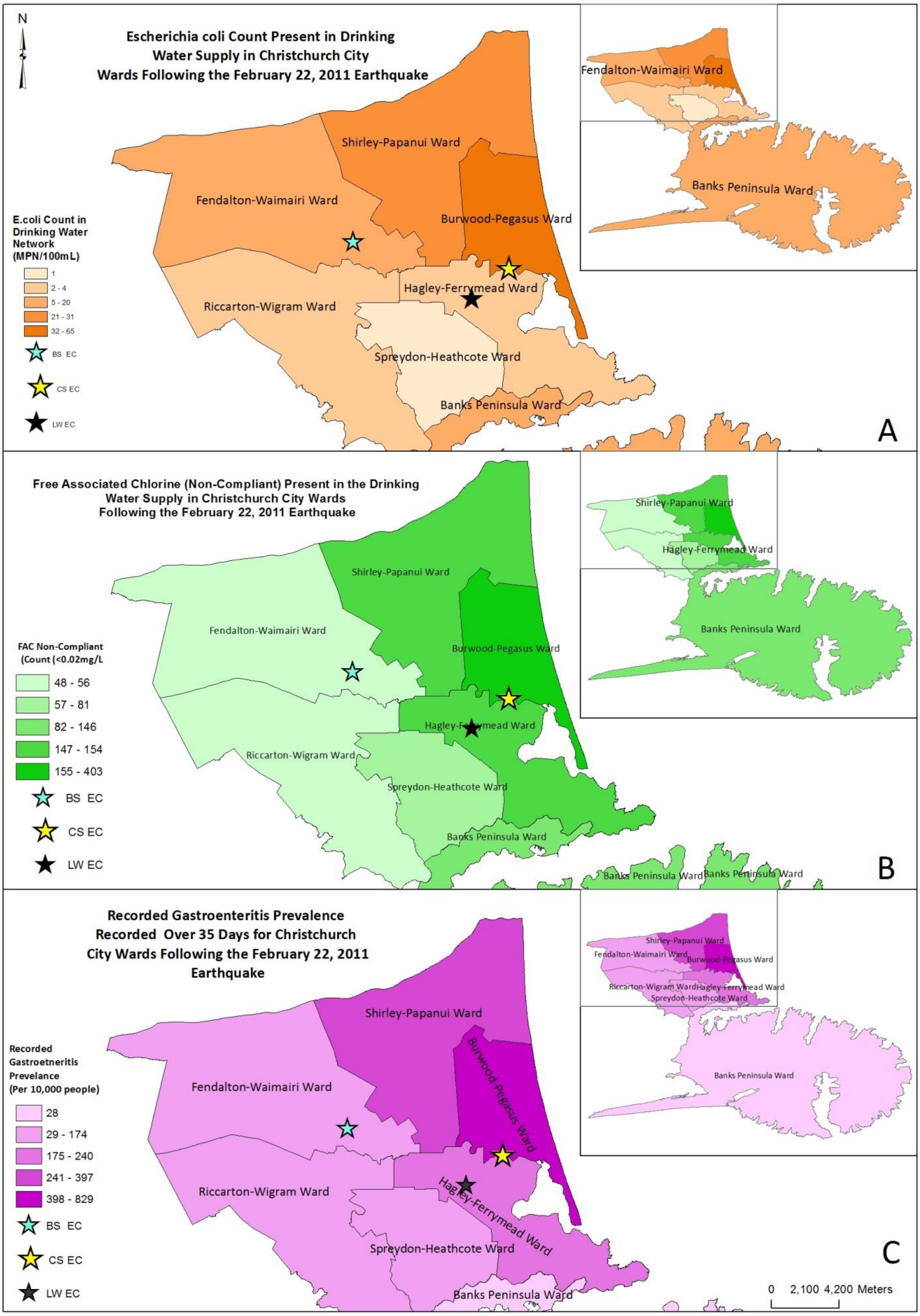

Figure 4-9: Ward Representation for recorded gastroenteritis prevalence and gastroenteritis agents—Escherichia coli and FAC (non-compliant)-following the February 22, 2011 earthquake. Abbreviations are BS EC=Burnside High School Emergency Centre, CS EC=Cowles Stadium Emergency Centre, LW EC=Linwood High School Emergency Centre.

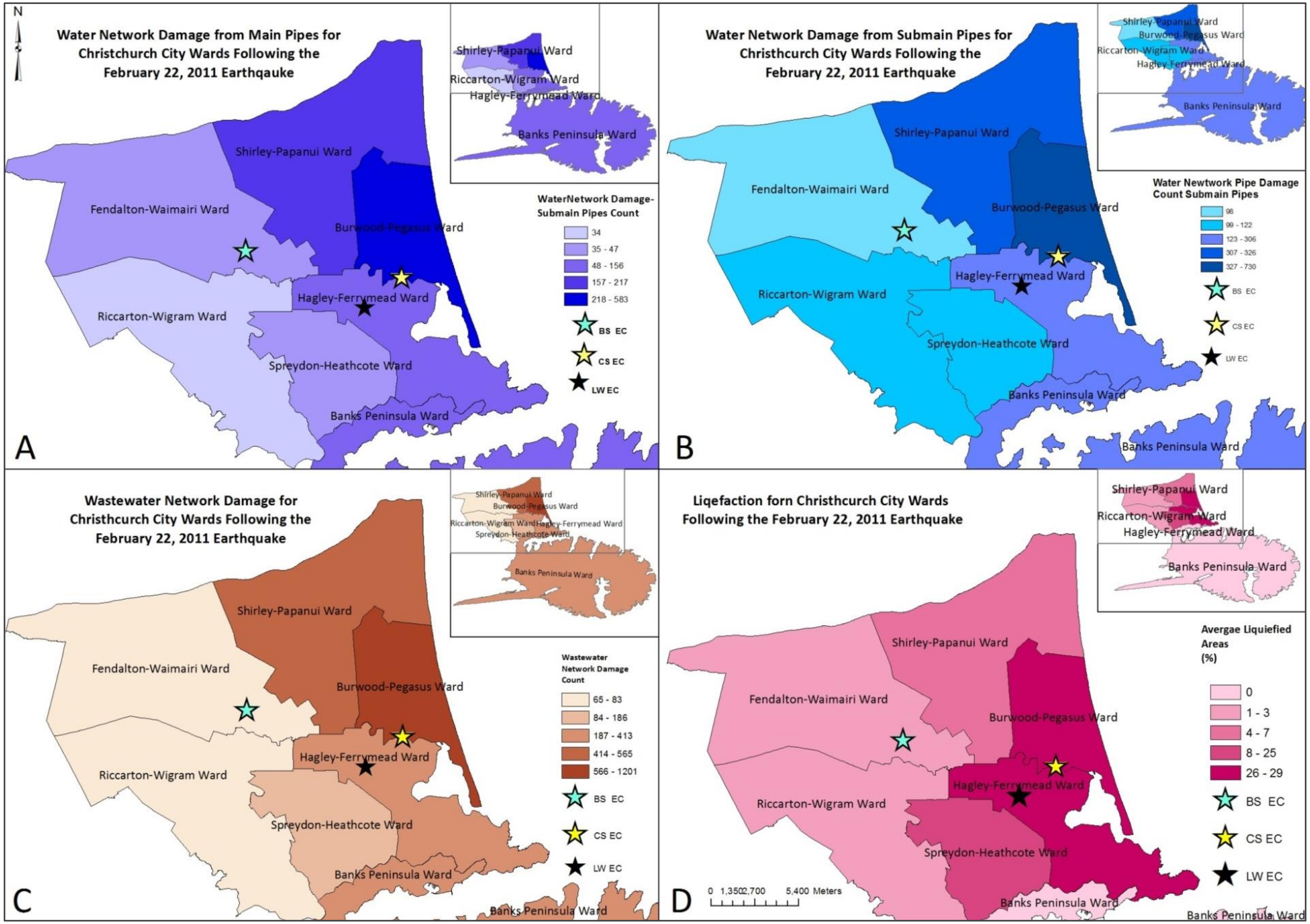

Figure 4-10: Ward representation for infrastructure damage: water (main and submain pipe damage), wastewater and liquefaction ground damage (lateral spread and surface ejecta) following the February 22, 2011 earthquake. Abbreviations are BS EC=Burnside High School Emergency Centre, CS EC=Cowles Stadium Emergency Centre, LW EC=Linwood High School Emergency Centre.

Table 4-2: Summary of gastroenteritis risk factors, infrastructure, and liquefaction ground damages per ward after the February 22, 2011 earthquake for two emergency centres.

Summary of Variables		Ward: Fendalton-Waimairi EC Name: Burnside High School (BEC)	Ward: Hagley-Ferrymead Name: Cowles Stadium (CEC)	Difference between wards
EXPOSURE	Ward Area (km)	7259.7	1561.4	65% decrease in Hagley-Ferrymead Ward
	Number of Residents	54342	31419	27% decrease in Hagley-Ferrymead Ward
	Population Density (Km)	1975	2185	5% increase in Hagley-Ferrymead Ward
GASTROENTERITIS AND ITS CAUSATIVE AGENTS	E.*coli* count in Drinking Water supply	20	4	67% decrease in Hagley-Ferrymead Ward
	FAC-NC Count in Drinking Water Supply	48	154	52% increase in Hagley-Ferrymead Ward
	Average Gastroenteritis Prevalence (per 10,000 people)	8.3	24.0	49% increase in Hagley-Ferrymead Ward
	Sum of Gastroenteritis Prevalence (per 10,000 people)	174	240	16% increase in Hagley-Ferrymead Ward
EARTHQUAKE INDUCED DAMAGE THAT MAY HAVE GIVEN WAY TO GASTROETNERITIS AGENTS.	Water Network Damage Count- Main Pipes	47	126	46% increase in Hagley-Ferrymead Ward
	Water Network Damage Count- Submain Pipes	98	292	50% increase in Hagley-Ferrymead Ward
	Wastewater Network Damage Count	83	413	67% increase in Hagley-Ferrymead Ward
	Liquefied Area of Lateral Spread and Surface Ejecta (%)	3	28	89% increase in Hagley-Ferrymead Ward

4.4 CONDUCTING INTERVIEWS

The one-off interviews were scheduled to last 30 minutes, but in most cases extended to one and half hours, especially for the focus groups. Initially the investigator planned to interview 30 participants equally from BEC, CEC and LEC. However, due to time restrictions, there were 16 participants from BEC to represent the west side of Christchurch and collective 14 participants from CEC and LEC to portray the east side of Christchurch. The CEC and LEC participants were collectively grouped because those participants interchangeably refereed to both of the ECs throughout their interviews due to their experience.

Axial coding textural analysis revealed top 10 keywords common in participants' transcripts using word frequency (Figure 4-11). Word frequency tool was a feature within NVIVO10 that isolated the emerging keywords. These keywords reflect what participants considered as important factors that averted gastroenteritis incidences at an EC. Hence, top 10 keywords framed the basis for selective coding to implore two key ideas: first, understand the context surrounding the keywords, and the second, interdependency of those keywords.

Selective coding identified two overarching themes that prevented gastroenteritis outbreaks at ECs: indirect and direct themes. The indirect themes were the EC type of building and EC layout. The EC layout was further influenced by the building damage, EC services, hygiene standards, security, types of people attending the EC, staff dynamics and lessons learnt. The direct themes were the preventive protocols established to avert gastroenteritis outbreak at the ECs. The proceeding sections provide a summary of *what* were the indirect and direct themes identified, and *how* the indirect themes acted as a prelude to emplace the direct themes are discussed in the Chapter Five, the discussion chapter. The raw accounts for each EC are described in Appendices M, N, and O. The concatenation of direct and indirect themes are summarised in Figure 4-12 to give an overview of how the three EC's averted gastroenteritis cases after the February 22, 2011 earthquake. The proceeding sections give detailed outlines of the themes.

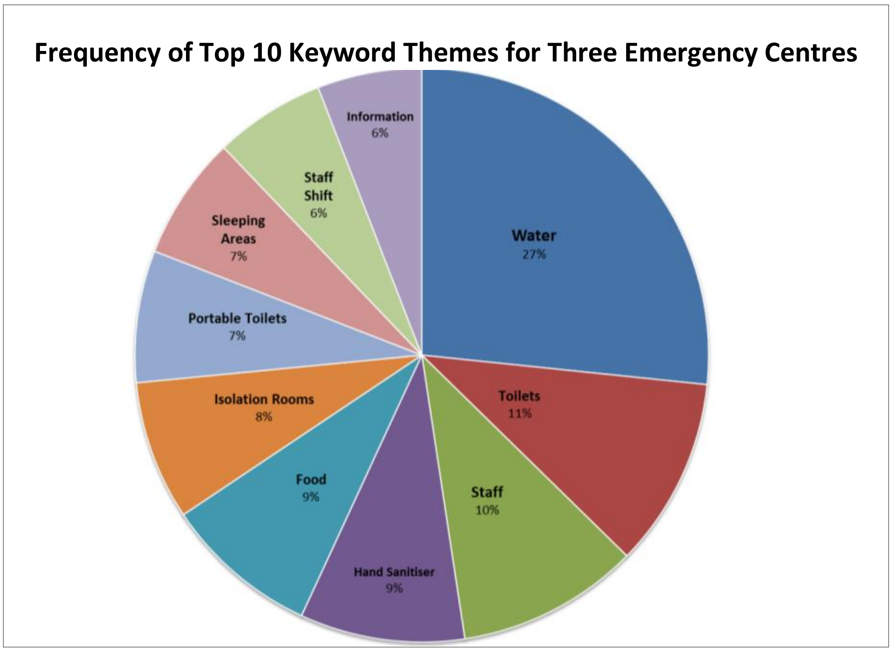

Figure 4-11: Represents the top 10 keywords identified from the interview transcripts. The percentages, accompanying each keyword are derived from the number of counts that a keyword has been identified in transcripts for the top 10 keywords selected. The three emergency centres are Burnside High School, Cowles Stadium, and Linwood High School.

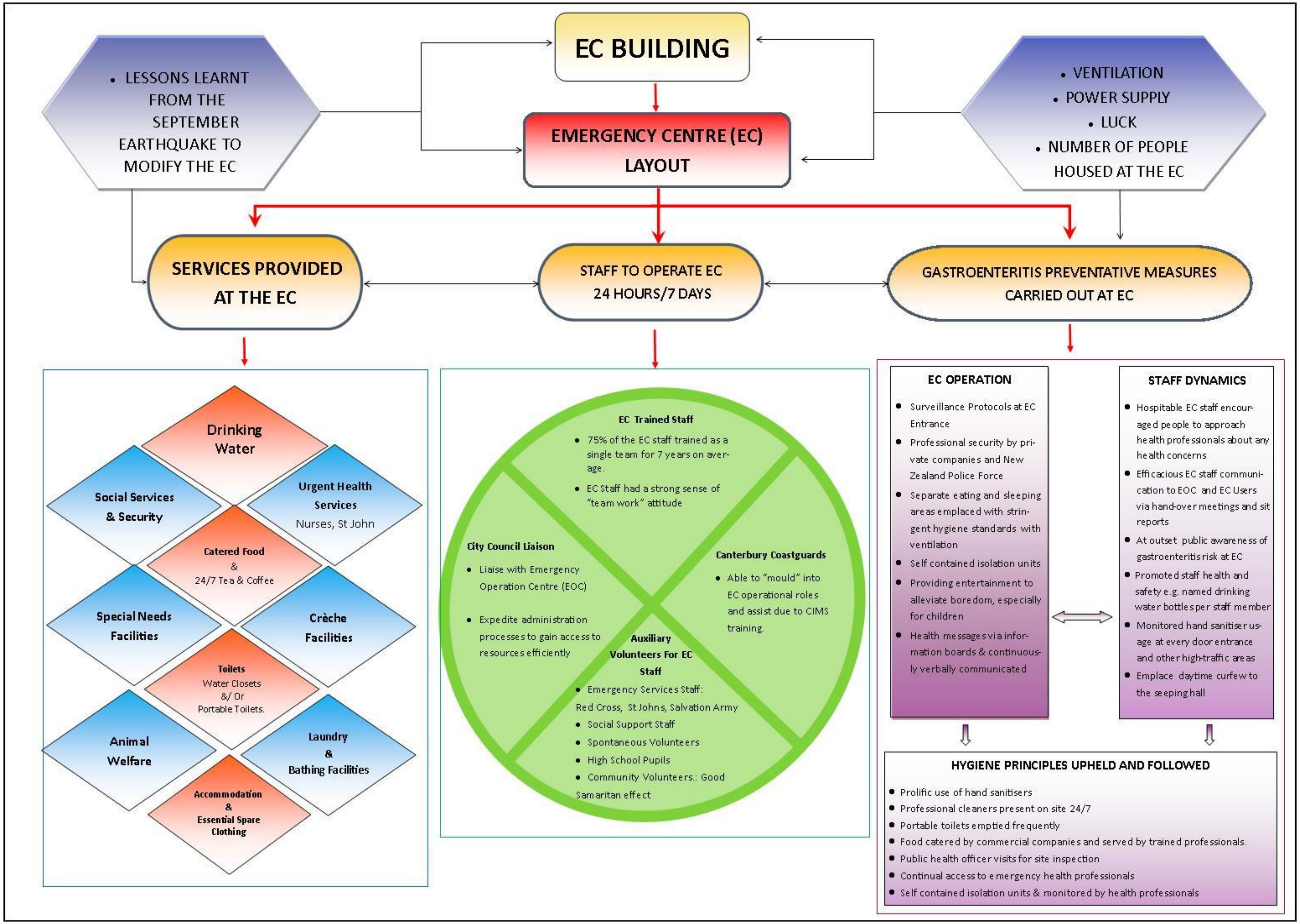

Figure 4-12: Showing the overarching concepts that averted a gastroenteritis outbreak at the three Emergency Centres (ECs): Linwood High School (LEC), Burnside high School (BEC) and Cowles Stadium (CEC). The study considered BEC and CEC for the February 22, 2011 earthquake while LEC was only opened for the September4, 2010 earthquake. The central concepts were the efficacious EC layout, which depicted and trickled other components, as shown on the diagram.

4.5 INDIRECT THEMES

The proceeding sections describe the influential indirect-themes that were common to the three EC layouts. Identified indirect-themes are collective reflections of common occurrences, practices, characteristics and observations from the interviews. Namely, the indirect-themes were EC building type, EC layout, building damage, EC infrastructure services, provision of food, accommodation and social services, security, types of people, staff dynamics, and lessons learnt.

4.5.1 EMERGENCY CENTRE BUILDING TYPE: HIGH SCHOOL VS. SPORTS STADIUM

Type of building used for an EC framed the foundation for other concepts. Building type influenced the type of infrastructure available, EC expandability, number of evacuees housed at the EC, which in turn depicted the EC layout, and number of staff needed to operate the EC on a 24-hour cycle. Two building types were identified from the interviews: a high school (LEC and BEC) and an indoor sports stadium (CEC). Both building types had unique advantageous and disadvantageous.

High school (LEC and BEC) ECs benefited from the common layout of a school; multiple classrooms in a building collectively called a classroom block. These classroom blocks were each serviced with essential infrastructure (such as lavatories, power and drinking water fountains) and equipped with school amenities—desks, chairs, tables. The classroom blocks provided separate sections to an EC layout that could "grow out" or contracted to suit ECs" needs and functions. A particular example utilising classrooms in LEC and BEC were multiple classrooms that were used as isolation rooms. A classroom was used as an isolation room to house an isolated individual or a family. The isolation units were equipped with lavatories belonging to the classroom block. At LEC, one unit had a kitchenette for isolated evacuees to utilise. If more isolation rooms were needed, more individual classrooms were opened within the classroom block. Similarly, BEC opened extra classrooms to provide religious requests, such as separate men's and women's sleeping area; and a prayer room.

As the number of evacuees expanded, BEC assigned classrooms to social services such as work and income for traffic management and privacy (Figure N-1).
Other distinct features of a school building were:

- **Principal's office**—At LEC senior management used it as an operation room at the outset

- **School cafeteria**—BEC and LEC used it as dining areas for safe food and beverage service where kitchen utilities such as water boiler was available for everyone
- **School gymnasiums**—BEC and LEC used it as sleeping space that EC staff could be rearranged. Gym equipment such as gym mats was an advantage during the first 36 hours whilst waiting for external supplies to arrive
- **School pupils**—BEC had school pupils, who knew the school layout. They often acted as "runners" delivering "messages and notes" as spontaneous volunteers for the trained EC staff at the EC.
- **Utilise school resources**-—using an atlas at the school in the reception area to identify tourists/evacuees with language barriers. School lavatories often had hand washing messages to maintain hygiene
- **Rubbish schools had skip**—to dispose rubbish using the school rubbish skits.

However, several disadvantageous of forming an EC at a high school included that evacuees and staff were disbanded across classroom blocks. This can hinder security efforts. Also, the community wanted the school re-opened for the students. Likewise, a sports stadium (CEC) had the particular advantage of using infrastructure and facilities catered for mass public events like basketball games. Infrastructure included installing emergency 10-15000L water tank and having access to stadium's power supply, which can be connected to a generator with ease. Facilities such as sporting equipment were utilised for children's entertainment (Table P-9). The large surface area inside the main stadium was separated by bleachers to provide multifunctional spaces (Figure O-1).

Multifunctional open-space created a sense of "togetherness" and community for stressed evacuees. From a security management point of view, it was easier to keep evacuees housed in a single building. At CEC, given that the CCC is the building's proprietor, the sport stadium can devoid the pressure of reverting to the building's original purpose. Unlike a high school, isolation units were housed within the main sports stadium that lacked the capacity to disband isolation units from the main stadium.

Nonetheless, both building types required the understanding and expertise of the building manager or caretaker to access the building's resources and facilities. For example, using a water outlet in one of the photography classrooms to install washing machines at BEC, and establishing communication systems for support section EC staff at LEC.

4.5.2 EMERGENCY CENTRE LAYOUT

The three ECs—LEC, BEC, and CEC—had different EC layouts: although there were common components among the three ECs, each EC layout had a unique fingerprint because of the building type and the staff team adds the character to an EC. The common elements were reception, registration, accommodation, social services, catering, security, information, public information boards, entertainment, and volunteer co-ordination. The core EC services are described in detail in Appendix P. Mainly, the building type features depicted the unique location of the core components outlined in Table P1-10 and shown in Figures M-1, M-2, N-1, N-2, O-1, and O-2. For example LEC and BEC had the capacity to expand the EC as required because of the classroom block set up. The main difference between the EC layouts was the location of the reception area. At BEC, the reception was located at the front of the EC entry driveway—away from the rest of the BEC sites. On the other hand, at LEC and CEC, the reception was based at the main entrance of the main building. This was not necessary better or worse, it was catering to the type of building EC was based on, although BEC's reception area greatly averted unnecessary foot traffic.

Generally, larger (or more spread) the EC layout, higher the number of evacuees housed which meant increased EC services required that can lead to higher number of staff required to maintain the EC 24 hours. Accordingly, LEC's maximum evacuee number was 650 which required about 40-45 staff. BEC housed approximately maximum 850 evacuees with up to 30 staff members (including spontaneous volunteers). CEC's highest evacuee number was about 300 with 26-30 staff members.

4.5.3 BUILDING DAMAGE.

The EC buildings did not sustain major structural damage due to the earthquakes, which meant adapting the EC layout in a post-earthquake environment. Before declaring the building as an EC, each building venue was approved by EOC and checked with a structural engineer. Only CEC inherited some minor damage to the building and surrounding areas. Minor damage included delimiting use of the food area to the first floor because of minor damage at the bottom floor (Figure O-1). As a result, access to the building was limited to the staircase entry— restricting disabled access. Also, CEC had liquefied areas, which hindered access to the private ambulance entry: an ambulance "got stuck" due to liquefied material (Appendix O).

4.5.4 EMERGENCY CENTRE INFRASTRUCTURE SERVICES

All ECs provisioned the core EC services with varying degrees, which are detailed with respect to each EC in Appendix P. This section summates the essential infrastructure—water, wastewater, power, food, shelter, social services—from Appendices M, N, and O.

4.5.4.1 WATER

The water supply was unavailable at BEC and CEC but functionally available at LEC following the initial hours the ECs were open to the public (Appendices M, N, and O). However, BEC regained limited water supply from the building's infrastructure within 12-36 hours, but refrained from use due to concerned health reasons. For example, manually shut off the water drinking fountains around the school on day one (Table N-1). Contrary, CEC did not resume water services because of the damages to the water network.

The ECs used commercial water tank (10-15000L) to reinstate the drinking water supply to the public, whilst bottled water was made available to the registered evacuees at the ECs (Figures M-1, N-1, and O-1). The ECs could not verify whether the water from the tank was suitable for consumption. Hence, information boards, located at front of the ECs, displayed warnings to boil the water for minimum 3 minutes, which was emplaced for Christchurch residents at the time (Figures M-1, N-1, and O-1). Furthermore, to manage the incoming resources at BEC a "quartermaster" role was required to manage stocks such as water bottles in the storeroom (Figure N-1). At CEC, a pre-installed water tank (a lesson learned due to the September 4, 2010 earthquake) was used to provide water to the building (Figure O-1). There was an incredulous demand for drinking water from the public. As a result, ECs modified their EC layouts by placing drinking water tanks closer to the street or at the EC entrance to delimit unnecessary foot traffic (Figures M-1, N-1, and O-1).

4.5.4.2 WASTEWATER SERVICES AND POWER

All ECs provided wastewater services using Portable Lavatories (PL), especially during those initial days the ECs were opened (Tables M-1, N-1, and O-1). The EC layouts had to be adapted to emplace PLs considering ease of emptying them for health reasons and efficacious people traffic flow (Figures M-1, N-1, and O-1). As the days progressed, wastewater services were supplemented using the buildings' laboratories in addition to existing PLs for BEC and LEC. On the other hand, CEC relied on PLs for the short duration it was open (Appendix O and Figure O-1).

At CEC the PLs were being filled much faster than they were being emptied. At the outset CEC closed the building lavatories (although they were functional) because of the surrounding wastewater network damages. Demand grew for PLs whilst CEC was open to the public. On the last day CEC was open, apparent forced entry into a building lavatory, with what appeared to be diarrhoea was found. Because of the above reasons, CEC was closed immediately due to health concerns (Appendix O and Table O-1).

The grid power supply at LEC was uninterrupted. However, grid power supply was unavailable for BEC and CEC for the first few hours, but returned by 7pm on the first night the ECs were opened to the public (Table N-1 and Table O-1). Both BEC and CEC used diesel generators of varying capacities as alternative power supplies for a short duration (Table N-1 and Table O-1). The grid power supply was constant henceforth as one participant said, “Once it was on, it was on”.

4.5.5 PROVISION OF FOOD

Provision of food and shelter required disparate sections within the EC. This requirement was heavily depicted by the building type that ultimately influenced the EC layouts because the largest spaces were reserved for food and shelter. All ECs adapted the main halls as disparate sleeping areas because of the large size, privacy, and ease to provide security (Figures M-1, N-1, N-2, and O-1). The food area at LEC was the Linwood High School cafeteria whilst BEC and CEC adapted disparate hall areas, which was pre-installed with the required equipment such as kitchens (Figures M-1, N-1, N-2, and O-1). All EC meals were catered externally and transported into the EC during meal times: each meal was delivered hot (Table P-5). Servery along with any food related duties were only administered, handled and maintained by Salvation Army. This was the common practice for all three ECs (Table P-5). To attend mealtimes, a Red Cross form was required to enter the food area because of the non-registered evacuees were attending the meal service, otherwise referred to by participants as “bystanders” (Appendix M). Security enforced this rule. Hence, the food area impacted EC layout because the need to emplace security, hand sanitiser stations, and carefully monitored footpaths to maintain strict hygiene standards.

4.5.6 ACCOMODATION AND SOCIAL SERVICES

The main halls for BEC and LEC were adapted as the sleeping areas whilst CEC utilised the segregated areas of the main stadium (Figure N-1, and Figure O-2). All ECs had bedding in the form of mattresses, blankets and pillows. However, LEC’s bedding was delivered 1-2 days after

LEC had opened (Table P-4) while BEC, for those first initial hours, used gym mats until proper bedding arrived on the first day. All ECs encouraged evacuees to vacate the sleeping area by day to maintain hygiene standards. The three ECs commenced cleaning the sleeping areas on different days—LEC day 4, BEC day 3, CEC day2 (Tables M-1, N-1, and O-1). Furthermore, during the night a security guard and a CD staff member patrolled the sleeping areas for security at the three ECs.

The social services "trickled- in" once the ECs opened (Tables M-1, N-1, and O-1). A comprehensive list of social services is provided in Table P-3. Social services provided essential access required by evacuees such as work and income. All ECs adapted the main sleeping area for social services, although BEC later relocated social services to individual classroom blocks as social services trickled-in to grow in EC size and to provide privacy. Because of the high demand for social services, CEC adapted multi-functional areas: social service area by day, sleeping area by night (Figure O-2).

4.5.7 SECURITY

Security presence aided to implement the EC layouts. A collective team of professional security guards, EC staff security and NZ Police provided security to the ECs. Security reinforced the EC layout following by monitoring people entering the EC (such as paedophiles, and persons of interest) and to prevent bellicose behaviour, especially at night. Security maintained EC cordons around the buildings and secured entrances (Figures M-1, N-1, and O-1). In addition, security ensured that the EC layout was followed by evacuees such as orderly food cues; implement hand-sanitising protocols before entering the food hall; and impose isolated evacuees to remain within the isolated area for health reasons. In particular, at LEC security was needed to ensure isolated evacuees remained in the isolated units (Appendix M and Figure M-1). Security in their respective uniforms walking around the ECs gave evacuees (and staff) a sense of "presence," "visibility" and a "safe" environment. Security intermingled with evacuees that gave "reassurance" to stressed evacuees.

4.5.8 TYPES OF PEOPLE

ECs welcomed evacuees from various backgrounds and characteristics. Three groups of evacuees were identified across the ECs: traditional, anxious and capitalise. Traditional and anxious evacuees comprised majority of the evacuees housed across all three ECs whilst capitalise evacuees representing the minority. Understanding these types of people helped the EC staff team to provide any assistance, sensitivity or services they may need.

Traditional evacuees were people and families that had lost their homes because of the earthquake without access to necessities that would otherwise be available. Families, individuals, elderly were included in this group. They genuinely needed a place to stay and access the services offered at ECs. Often these evacuees would attend to their own issues during the day, and return to the EC in the evening to sleep. In others, the situation was reverted: homes were safe, but had no access to food and water; and sought services of the ECs. Some traditional evacuees reflected low socio-economic status due to limited resources available. These evacuees were known to services such as Work and Income and Child, Youth; and Family services. This was most prominent at LEC. Also included in the traditional group were airport-transit evacuees. BEC had a travel agency service set up to help tourists and visitors obtain flights as well as to provide temporary accommodation (Appendix N). BEC catered to airport-transit evacuees because the EC was originally designed to receive those evacuees in a post-disaster situation.

Second group, anxious evacuees, consisted of people who were "psychologically stressed". People were anxious to stay at home: being with other people was a coping mechanism to alleviate anxiety. LEC and CEC had influx of evacuees into the centre when a moderate aftershock above magnitude 5 on the Richter Scale was experienced. Anxious evacuees were mostly, single parents, in particular single mothers, elderly, individuals living alone, and families who have not experienced earthquakes. For example, BEC received families from different nationalities—Egypt, Korea, Afghanistan, Pacific community— wanting to be around people. ECs also catered to religious needs and requirements. For example, separate sleeping areas for women and men. In this group, "most people would leave the EC and return at night to sleep". Part of this group was also mental health evacuees such as drug addiction and mental illness who needed to be in a supportive environment.

The capitalise group referred to evacuees purposefully taking advantage of the EC system referred to as "freeloaders". Evacuees would complete false Red Cross forms to obtain resources. For example at BEC, evacuees requested baby formula when a baby was not registered as part of the family on the Red Cross form. LEC had issues with a member of the public selling water in containers that was re-filled with water from the LEC water tank supply. Of the total evacuees housed in the respective ECs, about 5% of the LEC evacuees were considered "freeloaders" whilst 15% at CEC with less than 1% of the total evacuees housed at BEC.

Some evacuees were reluctant to go home: “they were nesting”. Provision of food, water, shelter, hygiene, social services, safety with “sense of community,” 24 hours meant that everything was provided. In particular, the food service given at the ECs; it was “better than what they would have at home”. Because of this, people came into the EC who did not need help. As EC and social service, staff began to enquire if evacuees required any resources to get re-settled; it was found that some evacuees stayed unnecessarily at LEC for up to 7 days. EC staff instituted asking questions to understand and address evacuees’ needs to counteract “freeloaders,” and reduce evacuee “nesting,” allowing resources to be available to those in need most. Reception staff—with sensitivity in mind—began to inquire from incoming evacuees “Welcome to our EC. How can we help you? What do you need?” When CEC was ordered to close, only about “10%” of the evacuees registered accepted the offer to be relocated to another EC: the rest went home.

4.5.9 STAFF DYNAMICS

Collectively, staff dynamics composed the following attributes: staff training; personal characteristics; job roles and supporting representatives from different organisations. These factors synchronically framed staff dynamics at all three ECs. Two key tools facilitated staff dynamics: hand-over meetings and staff operating rooms.

Half hour hand-over meetings took place during the overlapped period at the end of the current and beginning of the next eight-hour shift. These were mandatory meetings. Members of the upper management, team leaders (including representatives from additional organisations at EC shown on Table P-3) and necessary staff members were expected to attend the hand-over meeting. A handover meeting provided an opportunity for situation updates, communicating specific concerns, especially regarding hygiene or health reasons. Hand-over meetings, which lasted half an hour minimum, occurred in the support section room: a room reserved for EC staff only (Figures M-1, N-1, and O-2). The support section room acted as the organising-hub for the EC resourced with information boards; paper work to run EC; and communications gear such as radio (Figure O-2). Any issues such as hygiene, isolated evacuees, or wastewater infrastructure status were updated on the information board. This practice optimised communication between staff members to nurture a collaborative environment. As a result, staff maintained the EC layout whilst providing services to evacuees. Staff with the current shift person would walk around and update the next person of any issues, persons, and things that needed to be done.

The EC staff members were a collective team of different team representatives from multiple organisations that operated synchronically to provide EC services to evacuees. An EC staff team was a combination of Civil Defence (CD) staff, CCC liaison, the EC manager, venue manager; and other official capacity volunteers. The CCC liaison ameliorated administrative process to make CCC resources available to the EC efficaciously. Likewise, the venue manager—like the BEC caretaker or CEC manager— aided to modify the EC layout because of their knowledge in the EC building. For example, the BEC caretaker facilitated to connect drainage pipes to the washing machines (Appendix N). Another example, official capacity volunteers included Coastguards (CG) from Coastguard Canterbury. At LEC, CGs were needed to replace the resting staff, due to staff fatigue on day five. Because of CGs (Coordinated Incident Management System) CIMS training in command structure and emergency training, the CGs "moulded" into the CD staff team and improved the existing LEC operations (Appendix M-1).

Also, after the September 4, 2010 earthquake, "about 90% of the CD staff was available to volunteer". Yet, after the February 22, 2011 earthquake "only 40% of volunteers were available to work because the CD staff themselves were affected by the earthquake". Hence, CG volunteers were required to fill the CD team.

The CD staff members were efficient in managing the EC layout because team members knew each other's personalities, leadership skills, and strengths: they had trained as a single team over a long time. As a result, a CD volunteer's job role suited the volunteer's personality and

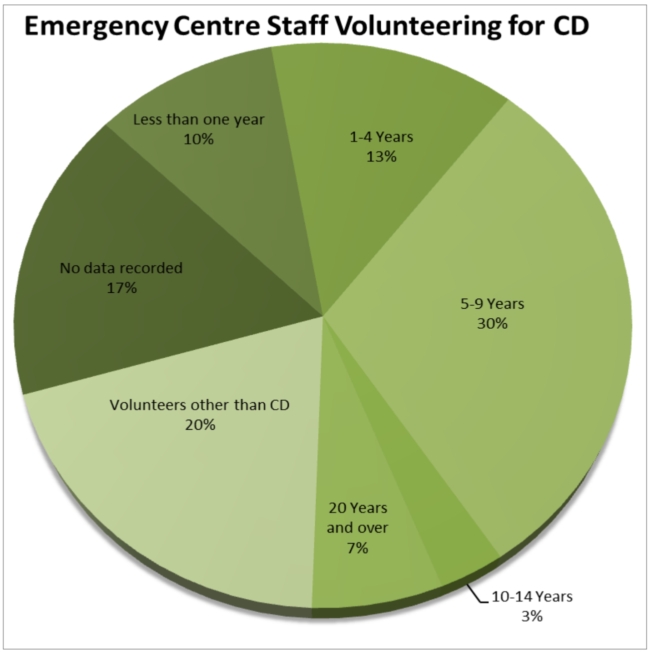

Figure 4-13: Average number of years the emergency centre staff has been part of an emergency centre staff team. Abbreviation: CD= Civil Defence

was conducted efficiently which in turn contributed to overall efficient EC operations. One member commented that the "team had practiced together [and] knew each other". The CD volunteers were "all friends". Up to 56% of the CD volunteers had trained together for 14 years, as shown in Figure 4-13. Volunteers knew which staff roles (whether welfare or support section) best suited their preferences and expertise: "You're wired for one or the other". For example, CD staff members who are mothers worked in the welfare section to help evacuees with babies or young children: "Character is crucial".

Specifically at LEC, a friendly teamwork hindered staff members' 'chain of command', because staff members were "friends": they did not want to hurt each other's feelings by critiquing decisions or ideas. Because of this, vacillating decisions inflicted the "chain of command" process. This situation waned when CG team helped with the EC shifts (Table M-1). The CGs' CIMS training reinstated the "chain of command" process by amalgamating CD training, and further instilled successful practices such as "implementing some training on health and safety issues like fire drills".

In addition to CGs, other volunteer groups supplemented the three, eight-hour shifts needed to operate the EC 24 hours. Those groups included neighbouring wards within in Christchurch city and outside the city. However, differences in CD training for the ward outside the Christchurch city caused some temporary section operational issues. Auxiliary counterparts of an EC staff team were spontaneous volunteers. All ECs utilised spontaneous volunteers to monitor hand-sanitiser stations. Unless spontaneous volunteers were previously known to the EC staff team, they were employed with caution, because spontaneous volunteers could not be vetted for their qualifications and security. In addition, LEC did not use spontaneous volunteers due insufficient training in CIMS. At BEC other volunteer groups included using school pupils because of their knowledge on the school and gregarious character. The pupils acted as runners for the CD staff taking notices for staff located around the BEC.

Community support from public members, volunteer groups and local companies played a vital role to contribute to the EC layout, which was collectively labelled as the good "samaritan effect". Community support supplemented to set up the EC initially and provided resources and personnel to maintain EC layout and functions. Community support included:

- Local companies donating clothing and food in trucks—Sanitarium Company bought breakfast cereal at BEC; local cafes bought food
- A coffee cart provided free coffee to CD staff; Tip Top Company gave free ice creams
- Cantabrians bought glut of cooked food especially home baking that was temporarily accepted but later declined and deferred to food banks
- Church groups cleaned lavatories during the early days at LEC
- Farmers bought 1000L water containers to BEC
- Members of the public offered accommodation analogous to a billeting system.

4.5.10 LESSONS LEARNT

Improvements identified because of opening an EC due to the September 4, 2010 earthquake, served as important learning curves: lessons learnt that was inevitably be useful for the February 22, 2011 earthquake and beyond. Hence, many participants felt that the September 4, 2010 earthquake was a "rehearsal" for the February 22, 2011 EC response. All three ECs were open after the September 4, 2010 earthquake for various short durations. BEC opened and closed after few days due to suspected building damage, and did not get an opportunity to provide a full service. CEC opened after BEC had closed.

However, LEC was one of the first ECs to open after the September 4, 2010 earthquake for remain open for 10 days. Lessons learnt at LEC spilled over to CEC and BEC, some of which were:

1. The EC staff to be in an overarching manner to "micro-manage" their roles instead of concentrating on one particular task like cleaning.
2. Through prior company arrangements have professional cleaners and security on site 24 hours from day one the EC is opened to the public.
3. The EC venue to store hand sanitiser supply to last the first 24-36 hours, which enables EC staff to inculcate good hand sanitising habits from the outset to evacuees.
4. A staff roster enables EC staff to have a "stand down" period by limiting a single eight-hour shift per day with maximum of five continuous shifts within a week.
5. A single-page health and safety brief sheet for staff with the EC layout overleaf at CEC after the February 22, 2011 earthquake.
6. From the outset, provide shower services at the outset and establish a shower roster.
7. At BEC, the support section room got shifted to reflect school building changes for better radio reception.
8. A quartermaster role was established at BEC to organise the storage room when resources arrived into the EC—milk powder, nappies, hand-sanitisers and water bottles— that ameliorated time delays to find resources.

4.6 DIRECT THEMES

4.6.1 PREVALENCE OF GASTROENTERITIS AT EMERGENCY CENTRES

All three ECs received evacuees showing or later progressed with symptoms of diarrhoea, when the ECs first opened to the public. LEC had a family showing diarrhoea symptoms and vomiting (Table M-1) whilst BEC had 1-2 people with diarrhoea (Table N-1). CEC showed multiple symptoms of diarrhoea via high usage of portable lavatories. At all ECs, the isolation units were occupied with a range of illness such as flu, immunodeficiency, insulin-dependent diabetes and dementia.

However, in the context of hundreds of evacuees using the LEC and BEC, only about "5%" of evacuees showed diarrhoeal symptoms whilst CEC showed about "40%" showed symptoms of stomach pains, fever, vomiting and diarrhoea. In all ECs, ill-health issues were immediately dealt via on-site health professionals. Nonetheless, given the presence of observed diarrheal illness, the following protocols were emplaced—which are highly interwoven—to prevent gastroenteritis outbreaks collectively from the three ECs. These protocols gave opportunities to manage any present issues; henceforth, embed those resolved issues as mitigative factors: preventive protocols born from theory but emplaced because of practical merit. One interview participant believed to have gotten diarrhoea from a pen, because evacuees were burrowing the staff member's pen frequently. Luck, which all participants believed also, played a role to prevent gastroenteritis outbreak.

4.6.2 PREVENTIVE PROTOCOLS CARRIED OUT AT THE EMERGENCY CENTRES

A concatenation of protocols incorporated into the different EC core services. The protocols included asking questions at the EC entrance; professional security; services offered at EC; hand-sanitisers at every entrance "gates"; separate areas within the building—sleeping, food and animal areas; isolation; health messages; and boredom alleviation amongst children. The following sections explain the concatenation of practices.

4.6.3 EMERGENCY CENTRE ENTRANCE: RECEPTION AND REGISTRATION

Reception staff, at registration, commenced to ask evacuees questions about any ill health symptoms evacuees had experienced during the past day: "Have you in the past 24/48 hours had a cold or something". Red Cross staff was also trained in First Aid and vigilant for evacuees showing general ill health. Any health concerns that evacuees expressed were referred to St John ambulance staff. This acted as the first surveillance point at the EC.

At CEC, reception staff was equipped with a flow chart for procedures concerning health. Reception staff forwarded any health concerns to St John, who would make the decision to attend evacuee(s) at isolation or transported to hospital for further medical treatment. In doing so evacuees received information from the allied medical professionals and alleviated untrained responsibilities from the EC staff at reception.

Professional Security reinforced preventive guidelines establish at the EC. Security presence forestalled any inappropriate behaviour such as paedophiles and bellicose evacuee behaviour, especially when accessing food or social services. Moreover, presence of security prevented lax attitudes within the EC for "prolific" use of hand sanitisers, in particular during meal times.

4.6.4 SERVICES OFFERED AT THE EMERGENCY CENTRES

Another surveillance protocol was provision of services provided at the EC (Appendix P). EC services included access to essential infrastructure (sewerage facilities, drinking water, and power), social services, food, and social services. ECs monitored available resources to provide EC services with adequate sanitation, hygiene and access to health-affiliated facilities. Constant communication with EOC, the EC to obtained depleting resources to provide consistent EC services. To do this, EC retained communication with EOC to obtain depleting resources. For example high demand for drinking water and emptying portable lavatories required services initiated from EOC (Tables M-1, N-1, and O-1). Further, health inspectors from Canterbury District Health Board (CDHB) visited the ECs. LEC did not receive health inspectors whilst it was open to the public. The health inspectors isolated areas for improvement such as mopping the floors in the crèche area at BEC. All participants believed that by providing the mandatory services, especially wastewater services and drinking bottled water coupled with hand sanitisers, acted as the main preventive protocols.

4.6.5 HYGIENE AT THE EMERGERNCY CENTRES

The size of the EC layout and increasing number of evacuees housed ultimately required professional cleaners to maintain adequate hygiene standards. LEC had some hygiene issues for the first two days due to the welter of evacuees entering the EC. Consequently, EC staff members were inundated with work; coupled with a church group volunteering, to clean the EC. Initially, the LEC staff members underestimated the effort required to maintain hygiene levels (Table M-1). Nevertheless, once professional cleaners were on site on the third day (and coupled with hand-sanitisers) the hygiene levels greatly improved: a lesson learnt (Table M-1). Similarly, BEC and CEC promptly hired professional cleaners, and stayed on site 24/7, to professionally clean the ECs as required: implementing a lesson learnt from September 4, 2010 earthquake (Table N-1 and O-1).

Using hand-sanitisers became a customary hygiene habit at all three ECs. At BEC, some evacuees began to body-wash in the lavatories on day three that instigated BEC to provide washing machines, dryers and portable shower unit beginning on day four (Table N-1). To ensure hygiene levels were practically established, BEC and CEC underwent a health inspection from a CDHB public health officer (Appendix N and O).

4.6.6 HAND SANITISERS

All participants believed "prolific" hand sanitiser usage was the panacea that prevented a gastroenteritis outbreak at ECs, although some participants thought it was "overkill" (Appendix N). It was mandatory to use hand sanitisers; "a blanket policy" for everyone including staff. A hand sanitiser was present at the entrance, exit and corridors of every building; all social service desks; sleeping areas; crèche area; isolation units; food area; reception and registration: anywhere with a door, room or a table surface a hand sanitiser was found.

In particular, at BEC two gates accompanied by CD staff acted as "choking points" (solid red line in Figure N-1). No person could pass the choking points without using a hand-sanitiser. EC spontaneous volunteers—such as school pupils at BEC—actively squirted hand sanitiser onto people's hands to make sure people used hand sanitisers: "Quiet reliant on hand sanitisers being the killer all, making sure you got squirt once; you got squirted 15 times". At LEC, the hand sanitisers were mounted to the wall. At BEC, For example, if an evacuee or a staff member planned to make a single journey from reception to the food hall via registration, an evacuee would have to apply hand sanitiser six times minimal (once at reception, registration, "choke gate", leaving the registration building, entrance to food hall, before eating).

LEC ran out of hand sanitisers during the first couple of days and was not being replaced but was rectified within the first couple of days; henceforth, hand sanitiser supply did not deplete (Table M-1, N-1, and O-1). Lessons learnt from the September 4, 2010 earthquake meant that the supply for hand sanitisers were already in storage at the ECs. Hand sanitiser usage commenced the moment BEC and CEC opened to the public. Largely, evacuees were receptive to "prolific" use of hand sanitisers. Inordinate hand sanitiser supply enabled EC staff to maintain uninterrupted hand sanitiser practice: "endless supply of hand sanitisers," "we could sterile Christchurch". In addition, staff also underwent intense hand sanitiser regime compared to evacuees. Each staff member was equipped with a personal hand sanitiser at the beginning of each shift. Staff members were encouraged to use hand sanitisers whenever needed. At LEC, the EC staff used hand sanitisers whenever minimal cleaning was done or hugging evacuees because staff members were well aware of the risk of a sick staff member.

4.6.7 SEPARATE AREAS REQUIRED

Essential components of the EC operated in disparate rooms that were depicted by the original building type: school or sports stadium. Disparate rooms—often housed in separate buildings—included meals, sleeping, St Johns, isolation units, and social services. LEC and CEC had sleeping; and social services in the same main hall area whilst CEC had all three areas in disparate sections. Designated areas created a physical barrier to prevent contamination unnecessary foot traffic. Food consumption was delimited to the food area and nowhere else (especially in the sleeping area), which provided a physical barrier for evacuees to move from one service to the next.

Monitored by security, evacuees unregistered to sleep at the EC were prohibited to enter the sleeping area; thereby, abating unnecessary foot traffic. In addition, services conducted in disparate rooms efficaciously facilitated EC staff duties such as closing sleeping area temporarily to clean and ventilate the area. More importantly function of disparate rooms enabled to keep one integral EC function away from main heavy traffic EC areas: isolation rooms.

4.6.8 ISOLATION

A main protocol that participants believed to have prevented gastroenteritis outbreaks at ECs was the establishment and practice of isolation rooms. Isolated rooms, located away from the busy areas of the EC, were equipped with integral amenities—drinking water bottles, bedding, lavatories, food and emergency medical attention—for the evacuees occupying the isolation rooms. St Johns ambulance and affiliated medical staff such as General Practitioner (GP) doctors and nurses attended to isolation rooms because of their medical background. The CD staff did not attend to isolation room queries. Security dissuaded evacuees in isolated rooms to enter main EC areas because of health and safety concerns. LEC required this security persuasion for some isolated evacuees. Professional cleaners commercially sterilised the vacated isolation rooms.

The isolation rooms required disjointed sections of the EC, away from the mainstream of EC functions. LEC and BEC adapted classroom blocks that were serviced with separate lavatories and PLs. At CEC, a segregated “triage” area incorporated isolation units staffed with health professionals (Figure O-2). The triage area was located within the main hall (where social services and sleeping areas were housed), but disassociated using bleachers and chairs (Figure O-2). The need for self-contained isolation units was heavily influenced by the EC layout because of the requirement to have disjointed sections within the EC. The need for isolation rooms was evident at LEC when the first family with diarrhoea arrived on the second day of LEC being opened (Table M-1). LEC and BEC denoted a block of classrooms for isolation—Figure M-1 and N-1—more classrooms were opened as the need for isolation grew.

Ancillary factors such as information boards and eliminating boredom amongst young children enacted to prevent gastroenteritis outbreak at EC (Table P-8 and P-9). Information message boards provided a communication method to display important health notices such as boiling water, medical contacts and importance of washing hands and if feeling unwell report to emergency staff (Table P-8). Three types of message boards were used at the three ECs: public information board; EC noticeboard for evacuees; and staff only information board placed in the support section room (Figures M-1, N-1, and O-2). At BEC, the EC staff reiterated health messages verbally during meal times. Participants believed that alleviating boredom amongst young children by establishing play area, crèche, and music prevented young children wondering around the ECs whilst providing supervised entertainment.

4.6.9 STAFF

EC staff practiced the above preventive protocols uninterruptedly. Intense training such as pandemic planning at BEC provided analogues insight into the risks and hygiene practices to avoid infectious diseases at an EC—"It was very much in everybody's mind". Hence, practicing rigorous hygiene standards for staff members were paramount: "can't run [a] WC [EC] with no staff". After a staff member finished a shift, they were encouraged to go home get rest, and wash clothing worn on the day. Staff members were attending 12-hour shifts during the first 2-3 days of the ECs being opened to the public. In doing so, staff fatigue emerged, especially at LEC, which led to impetuous decisions. To counteract staff fatigue, rosters were established and staff members were encouraged go home and get rest after their shift; and to put their family's wellbeing first. Furthermore, if staff was feeling unwell, staff members were encouraged to refrain from coming into the EC to commence their shift. These guidelines were further reminded during the hand-over meetings at the three ECs. In addition, staff members were encouraged to take a break and get fresh air every 40-50min, hand-sanitise after handling bedding, lavatories, people, pens; and before consuming food. Each staff member had a drinking water bottle with his or her name labelled on it. Any uncollected bottles were disposed at the end of each shift, "It was not worth the risk". Staff members were provided with gloves and masks to use.

Moreover, staff roles and characteristics contributed to uninterrupted hygiene protocols practiced. During a shift, staff job roles did not change; although, some job roles between different shifts changed to reflect EC size and functions. This ensured hygiene continuity in two ways: staff became familiar with evacuees' character and personalities; and staff yielded specialisation for their respective job roles. Hence, vigilant staff kept an eye out for change in personalities or showing signs of stress or ill health. Majority of the staff members carried notebooks—work that needed to be done— and passed onto the person doing the next shift. Staff members, particularly welfare section, had empathetic, friendly and approachable characteristics. Because of this the following hygiene practices were carried out pleasantly.

Enforced "prolific" use of hand sanitisers in a humorous and inviting manner using friendly expressions; whilst, reminding evacuees the importance of hand sanitising: "Cleanness is goddesses, sterilise sterilise, sterilise…let's do it again, you wouldn't want to get sick". This approach inculcated hand sanitiser usage: it instilled a good habit from the outset. Gregarious characteristics of the welfare support section team members meant that evacuees were comfortable to talk to staff members. At LEC, evacuees came forward about any health concerns: "We were sitting next to those people [family with diarrhoea] and we're not feeling too well". Staff could encourage evacuees to use EC facilities such as asking evacuees to have a shower or ask evacuees to vacate sleeping areas for cleaning. Further CD staff at LEC used spontaneous volunteers and some evacuees to maintain hand sanitiser stations as temporary avocation.

4.7 FUTURE RECOMMENDATIONS TO PREVENT INFECTIOUS DISEASES AT EMERGENCY CENTRES

Collative improvements from the three ECs to prevent gastroenteritis outbreak at an EC—in addition to lessons transferred from September 4, 2010 earthquake—are framed into five common groups. The common groups are EC type and operations; EC layout; EC services; and staff.

4.7.1.1 EMERGENCY CENTRE TYPE AND OPERATIONS

The gist of suggested improvements was establishing a "multi-mobile" plan with specific time frames to run an EC. An EC need a separate "multi mobile" operation plan for the first 3 days, 4-6 days, and then 6-10 days. For the first three days, an EC needs to operate with minimal resources whilst setting up to provide EC services, most likely with limited staff. Another separate operations plan for the next 4-6 days with an additional plan for the following 6-10 days to "wrap-up" the EC services and eventually closing. These stages require different set of resources, specialised people and number of staff to cater EC dynamics as time progresses. Further embedded in the "multi-mobile" plan is an EC staff member, preferably affiliated with the CDHB, that operate under the EC supervisor—under operations section—responsible for hygiene matters. This staff member needs to be provided with appropriate training—a "tool kit"—to attend to any hygiene matters such as monitoring hygiene levels across the EC or being vigilant for evacuees with any ill health. It enables additional information feed to the EC supervisor from a health-hygiene point of view, and relieves workload from the rest of the EC staff members. Collectively the "multi-mobile" plan grants adaptability for segmented operational periods, which were common to all the ECs (Table M-1, N-1, and O-1). This is important because nature of the post-disaster setting depicts staffing and spaces available in the EC building.

Future improvements included establishing small ECs across specific suburbs, in particularly the vulnerable suburbs with low socio-economic status, as opposed to ward representation. This would channel a local response by assessing specific needs of that community because local people understand their issues and needs. With CD input, localised ECs would allow resources to be distributed to those areas in most need first. Some participants suggested multiple organisations—like CCC, CD and Red Cross—hindered the EC response, and preferred to be housed under one organisation, CD.

4.7.1.2 EMERGENCY CENTRE LAYOUT

The EC layout improvements included evolving the existing EC layouts by implementing the following suggestions:

1. The EOC to provide cleaning, especially lavatories and professional security immediately via-pre-arranged agreements with companies. This is paramount. Closely followed by lavatories and drinking water made available as soon as possible.
2. Prearranged plans for food donated by members of the public are forwarded to other organisations like the food bank or a church group.
3. The information board outside the EC contain notices on not accepting food from members of the public, and advertise this message outside of the EC.
4. The EC layout can be further refined to "curb" evacuees even more to delimit "freeloaders" and facilitate more efficient foot traffic.
5. The EC layout is set up "big scale" and constrict as needed because it's difficult to operate on reverse.
6. The number of days an EC is opened to the public needs to increase from 4-7 days, which reflects the EC layout plans.

4.7.1.3 EMERGENCY CENTRE SERVICES

The EC services can be further enhanced by increasing the number of staff at reception to process the queues faster. Further, establish a health and safety briefing for evacuees at reception or registration: "Welcome to our EC, this becomes your home, these are our rules". It sets the EC expectations for evacuees and warns off "freeloaders". Likewise, adapt venues to vet spontaneous volunteers for their qualifications, and security before commencing EC duties. Provide shower services at outset and establish a shower roster. Finally, to improve EC services, establish a routine to clean the sleeping area from the outset, and encourage evacuees to vacate the sleeping area during the day—weather permitting.

4.7.1.4STAFF

Some of the suggestions put forward by staff to improve EC response were to train with other teams such as CGs or adjacent CD ward teams to be familiar with fellow colleagues to understand different team dynamics. Some participants also suggested more training on recognising stress and symptoms for isolating illnesses. Unique staff identify jackets would also aid to warn of members of the public imitating CD staff to gain EC access without registering. Finally, some felt cloistered during their shift without any updates on what was happening outside of the EC and some information from what was happening outside the EC may have helped.

4.8 CHAPTER SUMMARY

The summary points from the results chapter are outlined below. The Table 4-3 illustrates summary of quantitative results.

Table 4-3: Summary of results. Acronyms are as follows: CAU= Census Area Unit; EC =Emergency Centre; FAC-NC= Non-Compliant Free Associated Chlorine (<0.02mg/L), GT= Grounded Theory, HS= Hot Spot. The earthquake in the context refer to February 22, 2011 earthquake only, unless otherwise stated.

Test or method	Summary of results
1. Gastroenteritis thematic maps	Two clusters were identified over the South Island. Of all the recorded gastroenteritis point prevalence recorded, 91% of the recorded cases were in Christchurch area, thus Christchurch had the bigger cluster (Figure 4-1).
	Christchurch had 14-fold increase in recorded gastroenteritis point prevalence by comparing the recorded cases before (22-02-2010 to 28-04-2010) and after the February 22, 2011 earthquake over 35 days (22-02-2011 to 28-04-2011) (Figure 4-2).
2.Frequency Distributions	All frequency distributions showed similar power-law graphs: large frequency with low damage counts with small frequency (less than 10 CAUs) with high damage counts. Less than 10 (Figure H-1).
3.Spearman's Rho (σ)	Three levels of Spearman's Rho were identified: high, medium and low (Figure 4-3). • High level was collectively infrastructure damage and liquefaction ground damage • Medium level was indicated by FAC-NC • Low level was Gastroenteritis point prevalence and E.*coli*.
4.Thematic Maps Christchurch	Thematic maps for water network and wastewater network damage, liquefaction ground damage, FAC-NC, E.*coli* and recorded gastroenteritis point prevalence (post-earthquake) over the Christchurch area showed aggregated areas with similar damage counts for all factors except E.*coli* and gastroenteritis cases (Figures 4-4 and 4-5).
5.Moran's I	For all the factors, Moran's *I* was positive and showed clustered spatial patterns statistically (Table J-1).
6.Hot Spot Analysis	Hot spot CAUs were found. New Brighton was the most common HS for recorded gastroenteritis cases, FAC-NC, E.*coli* and water main pipe damage. Aggregated areas of HS were found amongst water, wastewater and liquefaction ground damage (Figures 4-6 and 4-7).
7.BYM Model	E.*coli* was the best factor that spatially explained recorded gastroenteritis cases, although statistically non-significant. (Table 4-1). E.*coli* counts were best explained by water damage (main and submain pipes); liquefaction ground damage and wastewater with some statistical significance. (Figure 4-8).
9.Earthquake Damage surrounding ECs	The Hagley-Ferrymead Ward (that had the Cowles Stadium EC) had 52% more damage for (with the exception of Escherichia coli E.*coli* counts), water; wastewater; liquefied area; gastroenteritis prevalence; and FAC. This ward also had higher population density in the area (Table 4-2)
8. GT	There were two overarching themes: indirect and direct themes. The indirect themes were EC type of building and EC layout, building damage, EC services, hygiene standards, security, types of people attending the EC, staff dynamics and lessons learnt. The direct themes were preventive protocols established.

Collectively, these results probe the following discussion: what is the relationship between infrastructure damages that can give rise to gastroenteritis-causing factors especially where EC's are established? More importantly, how did the indirect themes and preventive protocols avoided gastroenteritis outbreaks after the February 22, 2011 earthquake in Christchurch? These are explored in the proceeding discussion chapter.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

This thesis investigated two research questions:

1. Can the recorded gastroenteritis prevalence in the aftermath of the February 22, 2011 earthquake in Christchurch, New Zealand be spatially explained by the associated factors: earthquake-induced infrastructure damage, liquefaction ground damage (lateral spread and surface ejecta), and gastroenteritis agents?
2. What protocols were implemented to prevent a gastroenteritis outbreak at three Emergency Centres (ECs)?

The first question was addressed using quantitative methods, whilst the second research question used qualitative methods. The chapter is organised according to the structure outlined below:

- The chapter begins with a synopsis of results
- Interpretations of quantitative results and comparisons the findings with similar studies
- Interpretations of qualitative research with a focus on how the direct and indirect themes harmoniously interacted to implement preventive protocols; and compares the results to similar case studies from the literature review
- The research limitations and future work is identified.

5.2 RESULT SYNOPSIS

The following provides a synopsis of quantitative and qualitative results from this research:

1. There were two spatial clusters identified by comparing the recorded gastroenteritis cases for the South Island in New Zealand over 35 days following the February 22, 2011 earthquake. The bigger cluster was in Christchurch with 91% of the total cases recorded.
2. There was a 14-fold increase in gastroenteritis prevalence, by comparing recorded gastroenteritis cases over 35 days following the February 22, 2011 earthquake to the same time frame the year before (in 2010).
3. There was spatial clustering with statistical significance ($p<0.01$ and $p<0.05$ for E.*coli*) by using Moran's *I*, and hot spot analysis for each factor: water network pipe damage (main and submain), wastewater network pipe damage, liquefaction ground damage (percentage of liquefied area per CAU), and gastroenteritis agents-E.*coli* and FAC-NC. Henceforth liquefaction ground damage (lateral spreading and surface ejecta) will be

referred to as liquefaction ground damage. The statistical results for these are shown in Appendix J, Figures 4-6, and 4-7.

4. Spearman's Rho analysis indicated the existence of a tenuous, indirect association between gastroenteritis cases and the following factors: earthquake-induced infrastructure damage; liquefaction ground damage; and Non-Compliant Free Associated Chlorine (FAC-NC) (<0.02mg/L), but not E.*coli*.
5. Gastroenteritis point prevalence was best spatially explained by spatial distribution of E.*coli* counts as shown from BYM Modelling. In turn, BYM modelling identified that spatial distribution of E.*coli* counts was affected by liquefaction ground damage, FAC-NC, and damage to the main and submain water pipes.
6. The Hagley-Ferrymead Ward, where CEC was located, had higher population density, water and wastewater infrastructure damage, liquefaction ground damage; and FAC-NC, except E.*coli*, which was higher at the Fendalton-Waimairi Ward.
7. The qualitative analysis for ECs identified two themes called direct and indirect themes. The direct themes were EC entrance; services offered at the EC; hand sanitiser and hygiene; separate areas; isolation provisions; and staff. The indirect themes included EC building type; EC layouts; building damage; EC infrastructure; hygiene; security; staff dynamics; types of people; and lessons learnt from the September 4, 2010 earthquake.

5.3 QUANTITATIVE DISCUSSION

Two clusters were identified over the South Island, New Zealand, indicating apparent clustering of gastroenteritis cases in Christchurch. Some 91% of the gastroenteritis cases for South Island were located in Christchurch. This led to focus on gastroenteritis prevalence before and after the February 22, 2011 earthquake. This revealed a 14-fold increase in gastroenteritis cases[1]. However, this spike may not be due to the earthquake itself.

Frequency distributions indicated there were only about 10 CAUs with high counts for gastroenteritis point prevalence, and for the following factors: water damage (main and submain), wastewater, liquefaction ground damage, FAC-NC, and E.*coli*. However, thematic maps showed those CAUs were aggregated together around the central-eastern areas of Christchurch in a heterogeneous mix of damage intensities for all the factors except E.*coli*

[1] The 2010 data included only gastroenteritis cases as defined by Ministry of Health Communicable disease definitions by contract, the 2011 database included all enteric disease cases. Moreover, GPs in Christchurch had been alerted to the importance of notifying enteric disease, so there was an increase in reporting of such cases outside the normal reporting criteria, which led to the 14-fold increase in gastroenteritis cases. The student was not aware of this information prior to the completion of her thesis, and neither her supervisors were made aware of these methodological constraints. This finding does not negate the results of the thesis study itself, of which, the main aims were to identify any possible correlation between gastroenteritis cases with the earthquake-induced infrastructure damage, liquefaction ejecta on the ground, and the presence of gastroenteritis agents in the potable water along with mitigative factors that were carried to prevent gastroenteritis outbreaks at emergency centres.

(Figures 4-4 and 4-5). Common aggregated CAUs included Aranui, Avondale, Bexley, Chisnall, Ensors, Rawhiti, Linwood East, Linwood North and South Brighton. The common denominator for E.*coli*, FAC-NC, and gastroenteritis point prevalence was South Brighton. Thus, the results indicate that factors may be associated because of the common CAUs with similar damage counts. It can be considered that E.*coli* is less strongly connected to gastroenteritis prevalence than the other aforementioned factors.

Spatial clustering of aggregated areas using Moran's *I* indicated that those aggregated areas were statistically clustered with 1% probability (with 5% probability for E.*coli*) (Appendix J). This means there is 1% chance that the observed spatial patterns were due to chance for the considered factors: water damage (main and submain pipes); wastewater damage; liquefaction ground damage; FAC-NC; and recorded gastroenteritis prevalence. E.*coli* reflected a 5% probability; thus, 5% chance that the observed E.*coli* pattern was due to chance. The slightly lower probability reflects interspersed visual patterns observed in thematic maps (Figure 4-4 and 4-4).

Hot spot analysis identified areas with high and low counts. The number and location of Hot Spots (HSs) indicate that the eastern side of Christchurch had the highest damage that was statistically significant for earthquake-induced infrastructure damage (water and wastewater pipe damage) and liquefaction ground damage. Gastroenteritis cases and gastroenteritis agents showed interspersed HSs with South Brighton as the common CAU. This was initially observed in thematic maps. The results suggest that the specific set of factors may be influencing gastroenteritis point prevalence, E.*coli* and FAC-NC. However, all but one HS was identical to HSs identified for water (main and submain pipes) and wastewater damage, suggesting small HS clustering between the three factors.

Spatial statistics have thus far have indicated some level of association based on common CAUs with similar damage counts among the different factors. Spearman's Rho and BYM modelling showed how factors under consideration affected gastroenteritis point prevalence. The high-level measure of association between collective infrastructure damage (main and submain water pipes, wastewater) and liquefaction ground damage suggest they are heavily interlinked, especially main; and submain water pipes. These damages may have influenced FAC-NC counts because of the medium-level association between infrastructure damage, liquefaction ground damage, and FAC-NC. Thus, the presence of FAC-NC in water pipes (both main and submain pipes) may have been associated with the promotion of E.*coli* or gastroenteritis point prevalence on the grounds of low-level Spearman's Rho correlations (Figure 4-3). Compliant FAC is used to remove E.*coli* transgression in the drinking water supply; thus, it can be argued that the presence of FAC-NC, E.*coli* may sustain in the water supply (MOH, 2012). Studies have also indicated that E.*coli* has been associated with gastroenteritis (Bruce A. et al., 2009; Hall, 2004; Pennington, 2010; Wanke & Sears, 2008), there was non-significant statistical association between E.*coli* and gastroenteritis point prevalence, which strongly signals that in a non-spatial context there are factors, other than or in addition to E.*coli*, influencing gastroenteritis point prevalence. It is important to emphasise that Spearman's Rho is a measure of association and does not imply causation.

From a spatial context, the BYM by contrast showed how the considered factors affected the outcome of recorded gastroenteritis point prevalence. The results indicate that E.*coli* counts per CAU best explained the recorded gastroenteritis point prevalence: although statistically non-significant, a single E.*coli* count can increase the risk of gastroenteritis cases per CAU by 2.7% (Table 4-1). The results for E.*coli* are similar to those from Spearman's Rho suggesting statistical non-significance. Thus, it indicates that although E.*coli* counts and gastroenteritis may not be statistically significant, the spatial distributions between E.*coli* and gastroenteritis point prevalence are similar. In turn, the presence of E.*coli* in the drinking water system was best explained by liquefaction ground damage, FAC-NC, and damage to the water network with some statistical significance (Table 4-1). Thus, an increase in E.*coli* count of a single increment (per MPN/100mL) can increase the gastroenteritis prevalence by 6% for liquefaction ground damage, and 5% for FAC-NC. The statistically significant Estimated Effects (EEs) suggest that liquefaction ground damage and FAC-NC are positively correlated to E.*coli* count.

Arguably, the Spearman's Rho results may warrant the following observation: the presence of E.*coli* in the water supply results from liquefaction ground damage contaminating the damaged main and submain water pipes. Hence, liquefaction ground damage acts as the E.*coli* source. There have been past cases of E.*coli* entering into the water supply from cracked pipes (Swerdlow et al., 1992). This may be exacerbated when there are non-compliant FAC concentrations in the water network (<0.02mg/L). This in turn may enable E.*coli* to sustain within the damaged water pipe network, and may get distributed in the water reticulating network that was operating at reduced capacity to different parts of Christchurch (Gordon, 2011). This may explain the interspersed high E.*coli* count observed in the thematic maps, and again reflected in Moran's *I*; and HS analysis. Whether E.*coli* contributed to observed gastroenteritis point prevalence, as BYM modelling and Spearman Rho suggest, may have been influenced by other factors may have reduced this risk such as public health measures like boiling water for minimum three minutes (Dell, 2012).

Moreover, negative coefficients (shown in both models) for submain water pipes indicate that an increase in damage to water submain pipe *decreases* the point prevalence of gastroenteritis. This appears to contradict practicality. The submain water pipes are inextricably connected to the WSM pipes via an intricate pipe network. In addition, high level Spearman's Rho also indicates that damages to WSM and WSB are affected by one other. The same is also true for wastewater damages, which appeared to have no statistical influence (0%) on the E.*coli* count (Table 4-1). A significance of the practical context posits that a negative Estimated Effect (EE) is therefore more likely to be associated with covariates that are interacting with other covariates as well as the dependent variables within the BYM Model equations (Equation 4.1 and 4.2). This is because statistical insignificance does not necessarily indicate practical insignificance.

However, the residual maps highlighted areas where the considered factors alone do not entirely explain the recorded gastroenteritis cases, particularly in the eastern areas of Christchurch. Although the BYM maps for expected counts of gastroenteritis and E.*coli* are low (Figure 4-8A, C, and E), the corresponding residual maps (Figure 4-8 B, D, and F) indicate there are many parts of Christchurch, especially in the eastern and central parts whereby, the considered factors did not explain the spatial variation of gastroenteritis and E.*coli*. This means that other factors, which may influence gastroenteritis prevalence, were not included in the BYM Model. However, additional factors, such as those factors outlined in Figure 2-1, can be incorporated into the existing model with ease. Some of the factors not considered could also relate to assumptions made at the outset of this research. For example, assuming liquefaction ground damage to be a representation of geological properties such as soil composition may have also influenced the results. The residual maps also imply that gastroenteritis prevalence after the February 22, 2011 earthquake is CAU-specific. This means each CAU is affected by different factors expressed at different intensities. Thus, water contamination may be a significant factor in the eastern suburbs, but other factors such as food contamination may affect the western side of Christchurch. Therefore, understanding the unique risk profile for each CAU may provide a way to assess gastroenteritis prevalence following a disaster using a customised risk profiles for the Christchurch area. This can be particularly useful for local public health officials as part of an ID management protocol, especially for the more vulnerable CAUs that may be highly susceptible to gastroenteritis risk prevalence following a natural disaster.

Work conducted by Kingston and Semple (2005) identified local gastroenteritis clustering using spatial statistics with similar HS results in this research. However, some components of this research, and its results were comparable because of the data, which reflect the local environment. Spatial clustering using Moran's *I* for main and submain water pipe damage echoed work conducted by Piarroux et al. (2011), who used spatial autocorrelation techniques to understand clustering of water samples across the rivers following the Haiti Earthquake in 2011. However, the literature review was not able to identify a study that has incorporated thematic mapping, spatial clustering, and BYM modelling to explain the recorded gastroenteritis point prevalence in a post-earthquake context. By using both quantitative and qualitative methods, this research forms an integrated approach to study increased gastroenteritis prevalence following an earthquake using the Christchurch earthquake as a case study earthquake: recording the earthquake's fingerprint using mixed methods.

5.4 QUALITATIVE DISCUSSION

The quantitative analysis showed a range of damage caused by the February 22, 2011 earthquake. In spite of this, two Emergency Centres (ECs) were opened as part of the Civil Defence Emergency Management (CDEM) response. The locations of the emergency centres, Burnside High School (BEC) and Cowles Stadium (CEC) were subject to various amounts of damage to the surrounding areas such as water and wastewater network pipe damage (Table 4-2). In fact, ward that pertained to CEC had, on average, 52% more water network damage (main and submain pipes); wastewater network damage; liquefaction ground damage; recorded gastroenteritis cases and FAC-NC (Table 4-3). Despite this, there were no recorded outbreaks at the ECs (Dell, 2012). A participant mentioned that there were reports of "sewerage had exploded like bombs" in some areas, which meant evacuees might have trace particles of sewerage on their skin, especially when they were bringing food into the EC. This means evacuees may have entered, with a wide variety of pathogen sources. Thus, protocols implemented at ECs may have prevented gastroenteritis outbreaks. These protocols have been identified as themes in this research, as shown in Figure 4-12, and further discussed in the following sections.

The interview results imply that implementation of protocols played a major role in preventing gastroenteritis outbreaks at ECs. All three ECs had evacuees arriving with gastroenteritis-like symptoms. Although Cowles Stadium Emergency Centre (CEC) had significantly higher numbers of evacuees presented with a range of symptoms. One participant mentioned that about 30-40% of up to 400 evacuees showed symptoms of stomach cramps, and some diarrhoea, along with flu-like symptoms (Appendix O). All participants believed those evacuees arrived at the EC showing the symptoms rather than originating at the ECs. The direct themes identified were: EC entrance; services offered at the EC; hand sanitisers and hygiene; separate areas; isolation; and staff. This study indicates that the direct protocols implemented did help to avert a gastroenteritis outbreak. However, the results also suggest that the direct themes were highly dependent on successful implementation of the indirect themes. Namely, the indirect themes were: the EC building type; EC layouts; building damage; EC infrastructure; hygiene; security; staff dynamics; types of people; and lessons learnt from the September 4, 2010 earthquake. Even though some indirect themes and direct themes overlap, each indirect theme acted as a prelude to another direct or indirect theme. Therefore, the cumulative effects of the indirect themes explained *how* the direct themes were practiced that in turn averted a gastroenteritis outbreak. Hence, the focus of the qualitative discussion is to explain the implications of the indirect themes that led to establishing the direct themes.

5.4.1 EMERGENCY CENTRE ENTRANCE

The EC entrance (Figure M-1, N-1, and O-1) served as part of the surveillance measures to identify gastroenteritis outbreaks at the ECs. The surveillance measures were not a formal framework emplaced at the ECs, but a collation of actions from St John ambulance (Wellington and Christchurch), medical staff, public health officers, and sit reports aimed to identify gastroenteritis outbreaks or issues with public health significance. The importance of establishing surveillance systems, whether passive, sentinel or active, is highlighted by WHO (2005, 2011a) and Yee et al. (2007). Thus, the EC entrance was an integral component of the direct protocols implemented. Reception and registration services were located at the EC entrance. Staff at reception and registration asked evacuees if they had experienced any ill health recently. This acted as the first port of call from a preventive aspect. In return, it gave both the evacuee and staff members the opportunity to assess whether medical attention was needed from St John at the EC entrance. This meant that the EC layout needed to be orientated so reception and registration were placed closer to the EC entrance. Hence, if an evacuee required isolation, this could be dealt with at the EC entrance.

However, the choice of layout was limited by the existing EC buildings. For example, at BEC, the bike shed (located at the front of Burnside high school) was adapted to be the reception area—a lesson learnt from the September 4, 2010 earthquake (Figure N-1). CEC and LEC buildings, on the other hand, adapted the enclosed main entrances (Figure M-1 and Figure N-1). More importantly, people with the appropriate characteristics were needed to staff the reception and registration areas, because as one participant said, “Character is crucial,” where evacuees mentioned to staff if they were feeling ill, “We were sitting next to those people [family with diarrhoea] and we’re not feeling too well.” Hence, asking health-related questions at ECs was influenced by the EC layout, type of building, and staff characteristics.

5.4.2 INFRASTRUCTURE AND SERVICES

The second preventive protocol was the EC infrastructure and the services provided at the ECs (Appendix P). The layout of the ECs enabled services to be provided through alternative infrastructure (water tanks, portable lavatories and power) and staff dynamics (which included security staff) facilitated to maintain those services uninterruptedly. The EC layouts were positioned so that the PLs, water tanks, and shower units (at BEC only) where they were accessible to evacuees and staff for efficient foot traffic. For instance, the PLs’ location at CEC granted easy access for vehicles to come through the driveway and empty the portable lavatories (Figure O-1). The water tanks at the ECs were placed towards the main roads for easy public access to limit unnecessary public access into the main EC sites (Figures M-1, N-1, and O-1).

However, this study has noted the importance of providing portable lavatories at CEC. One of the main reasons, which led to its closure, was the inability to cope with immense demand for wastewater, especially in reduced circumstances. The lavatories for CEC were 1 lavatory per 18 people (Table O-1). This estimate was in line with the Sphere Project, which advises 1 lavatory per 15-20 people for high-risk settings such as an EC (The Sphere Project, 2011). Thus, the results suggest the need for number of lavatories changes to meet the local demand as the post-earthquake situation develops.

Co-operative staff dynamics reported any shortcomings (especially as the days progressed) during hand-over meetings. For example, BEC staff noticed that some evacuees were body-washing in the lavatories. To counteract this, alternative bathing facilities were established (Figure N-1). The security team also guarded the alternative EC infrastructure and services like the washing machines.

To provide additional services—such as social services— the layouts of the EC were adapted as the demand for those resources grew. At BEC, the social service area was shifted to another location and the space replaced with the dining area (Figure N-2). The CEC and LEC layouts were adapted to hold multifunctional spaces with some areas doubling as social services by day, and sleeping quarters by night (Figure O-2).

5.4.3 SEPARATE AREAS

Separate areas were required for different areas, like food service and isolation. Building type and subsequent level of earthquake damage governed this requirement. Existing building structures limited the number of separate areas available for use such as CEC having a capacious main hall, whilst BEC and LEC, had the capacity to expand (classroom blocks and gyms) as separate areas. Earthquake damage also restricted use of the buildings. Each disaster event, such as an earthquake, can damage buildings differently, thereby limiting use. This in turn had flow-on effects. For instance, CEC sustained minor damage to the ground floor of the dining area. Only the top floor was available for use, which meant the elevator was inoperable. Consequently, this prevented disabled access to the dining area.

Provision of food—catered externally for all three ECs—required separate areas, but was restricted by the type of building and the layout of the EC. In addition, staff did not accept the glut of baking from the community, because of the inability to verify hygiene standards. Additionally, the EC layout ensured that security monitored foot traffic into the food area. At LEC for instance, the school cafeteria was used as the dining room for provision of food (Appendix M).

5.4.4 ISOLATION

Isolation was an important direct theme that all participants identified as a preventive protocol (Figure 4-11). Building type dictated the nature of isolation units at the ECs: separate classrooms for a school (BEC and LEC) or "triage" set up that was separated by bleachers (CEC) (Figure O-2). Medical personnel staffed the isolation units. This meant trained personnel were available to deal with health issues, thereby alleviating the pressure from the CD staff. This in turn affected the EC layout, because health professionals were permitted to manage the isolated areas and attend isolated evacuees. Security enforced this cordon, and guarded the area to discourage isolated evacuees from entering the main EC area. This enforcement was necessary at LEC. Thus, two main indirect themes affected establishment of the isolation units: building type and security.

5.4.5 HYGIENE AND HAND SANITISERS

Professional cleaners were on-site 24 hours a day to maintain the ECs to hygienic standards. The need for professional cleaners and for them to be constantly on-site was an important lesson learnt from the September 4, 2010 earthquake. The presence of security actively discouraged evacuees unwilling to participate in hygiene protocols, especially during food service. The hand sanitiser usage was "prolific" and was thought by all participants to be the panacea that prevented gastroenteritis outbreaks at the three ECs. However, to implement and maintain a hand sanitiser system whilst the EC was open required three indirect themes: lessons learnt from the September 4, 2010 earthquake, EC layout, and staff.

The experience of the September 4, 2010 earthquake led ECs to store hand sanitiser supply at the venue, in particular at LEC. Therefore, when an EC opened to the public, staff members were able to inculcate good hand sanitiser protocols from the outset. The main strategy used to denote hand sanitiser stations was "everywhere," but particularly at "choke-points," and door entrances that led into separate EC services (Appendix M, N, and O). As a result, the locations of hand sanitiser stations were conditioned by the EC layout because of the need to establish separate areas (such as food, sleeping quarters, PLs, isolation areas, animal welfare, and places dedicated to social services) to prevent cross-contamination, maintain hygiene and manage evacuee traffic flow. Inevitably, locations of the hand sanitiser stations were denoted by the separate sections, and location of those separate sections, which depended on the EC building. Staff dynamics, especially auxiliary volunteers (such as BEC's school pupils), were the driving-force, behind implementation of the hand sanitiser system before the EC was opened to the public (Section 4.5.9). However, it is plausible that if the EC layouts were practically inefficient, and staff duties were carried out unproductively, then the high volume of hand sanitisers may not have been as effective. This is because the hand sanitisers may not have been placed in effective locations using the EC layout to identify areas of high traffic flow and vulnerable areas.

5.4.6 STAFF DYNAMICS

The timely activation of direct themes were directed by staff dynamics and implemented over days (Appendices M, N and O). It could be argued that without the coherent staff response, many of the preventive protocols would not have been implemented effectively. Simple preventive protocols alone will not suffice, and there needs to be a support network to implement, promote, and maintain preventive protocols. Hence, staff members may be viewed as the most important preventive protocol, because they amalgamated preventive protocols for the duration of the time when ECs were open.

The indirect theme, staff dynamics contributed to the success of preventing gastroenteritis cases. Staff dynamics included staff training, personal characteristics, job roles and auxiliary volunteers. An example would be, staff members identifying evacuees by type of evacuees to prioritise EC services according to need. Gregarious staff promoted hygiene standards by asking evacuees to vacate the sleeping area for cleaning, whilst activities were set up outside to engage the evacuees while cleaning was being carried out. The dynamic staff team, for instance high school pupils, actively promoted evacuee participation in hygiene standards by going from person to person and squirting hand sanitiser.

The dynamic composition and roles of a staff team (Civil Defence staff, Canterbury Coastguards, school pupils, social support, Christchurch City Council liaisons, spontaneous volunteers, community volunteers—church group) helped ensure that hygiene protocols and other staff duties were managed effectively (Figure 4-13). This research has found that it was the unique members from different organisations, which composed the staff team enabled in turn to adapt within a demanding environment. Although some staff members reported diarrhoea symptoms at LEC after 5 days (Table M-1). The establishment of staff rosters provided staff mandatory rest period. Senior staff members encouraged staff members to remain at home if they were feeling unwell.

It can be argued that proactive community volunteers and groups may also have helped to avert outbreaks at ECs by bringing in resources when the ECs first opened to the public. The community groups and volunteers included church groups coming into LEC to clean; companies donating blankets and other goods; donated blankets from commercial companies; and members of the public offering temporary accommodation for evacuees. This study also implies that "luck" played a major role in averting gastroenteritis outbreaks, because there could easily have been staff shortages or excessive numbers of evacuees arriving at ECs with pre-existing health problems.

5.4.7 FUTURE IMPLEMENTATION

Identifying the future improvements to prevent gastroenteritis at an EC can improve the existing preventive protocols. The study suggest that there needs to be more signage near the water tanks notifying to boil the water (in compliance with the health notice that was issued to boil water for a minimum of three minutes).

One suggestion put forward by an interview participant was to consider a "multi-mobile" plan. This would involve having different EC operating plans for different time frames whilst the EC is open to the public. A plan for the first 24 hours, followed by another plan for next 3-4 days, with a separate plan for closing the EC. The multi-mobile plan suggests delineating a specific job role for monitoring hygiene levels equipped with a "took kit" that would operate under the Emergency Centre Supervisor (ECS). This can complement the CDHB visits and relieve additional workload from staff. This suggestion can complement the public health efforts after a disaster in a pro-active manner. This is to reflect modulating resources, EC staff, and specific skills required to reflect the changing needs of the EC. Under the CDEM Act 2002 in New Zealand, an EC normally operates for 2-3 days as temporary accommodation, but this study has shown that ECs were opened up to a week and more, which reflected the nature of the disaster, and needs of the people in a post-earthquake environment. This finding is also noted in CDEM (2002).

A second suggestion put forward by participants included setting up the EC "big scale" and constricting in size as needed. Of a particular suggestion mentioned by another participant was setting up a number of ECs that are resource specific at different suburbs, which is driven by local knowledge. This idea is also being suggested by Mitchell (2012) and as a recommendation following the Japan earthquake of 2011 (WHO,2011a; WHO, 2011b).

From an international context, the protocols identified in this study followed the same guidelines for managing communicable diseases after a disaster or at an EC as recommend by CDC (2011); ESR (2012a); WHO (2006), and highlighted in Table 2-2. The direct themes implemented were similar to those practiced at the Megashelter following Hurricane Katrina in 2005 (Yee et al., 2007). For example, asking staff to refrain from working if they were feeling ill, using hand sanitisers and isolating rooms. However, whereas the Megashelter implemented those practices on a large scale only after an increased incidence of gastroenteritis was observed, the ECs in this research implemented such measures on the first day of operation, sometimes within hours of opening to the public.

As Yee et al. (2007) suggest multiple exposure paths contributed to over 100 gastroenteritis cases at the Megashelter, and multiple protocols were necessary. All ECs in this research used a blend of indirect themes to implement the direct themes, even though LEC had a slightly delayed response, because the September 4, 2010 earthquake was the first time that ECs have been opened for such durations in recent times. Hence, it can be argued that blending different protocols at the ECs studied in this research may have averted a gastroenteritis outbreak at the three ECs. Thus, the findings suggest that indirect themes may have helped to implement the direct themes. Even the ECs setup after the Japan earthquake in 2011 reflects some of the direct themes shown in Figure 4-12, but does not place emphasis on the indirect themes.

The qualitative results from this study posit that indirect themes may underpin the success rates of preventive themes carried out at various ECs. This in turn highlights the importance of understanding the indirect themes, and how they can be used to develop preventive protocols. Furthermore, this study has identified the possibility of requiring CAU-specific spatial modelling to explain gastroenteritis point prevalence, which complements the localised qualitative analysis, thereby setting the precedence to study gastroenteritis prevalence following a disaster.

5.5 LIMITATIONS

The investigative methods used in this study implicated three major limitations: Modifiable Areal Unit Problem (MAUP), ecological bias, Simpson's paradox, detection, multicolinearity, and recall bias. The first five limitations were specific to spatial regression analysis (aggregated table, thematic maps, spatial autocorrelation, HS and BYM modelling) whilst the last related to the qualitative component of the study.

5.5.1 MODIFIABLE AREAL UNIT PROBLEM

The MAUP refers to the possible source of error due to aggregation of data into predefined spatial unit (CAU, otherwise known as aerial units) because of administrative reasons (Openshaw, 1983). This is a limitation because changing the scale or the spatial resolution—otherwise known as zonal boundary—will also change the appearance or pattern. Figure 6-1 illustrates these concepts. When the resolution changes from A to B in Figure 6-1, a cluster (or a peak) is identified. Likewise, depending on how the boundary is defined, a different spatial pattern is observed (Figure 6-1C). Thus, by changing the scale and boundary of a study area (CAUs in this study), different spatial patterns are obtained, which ultimately will make a map appear different.

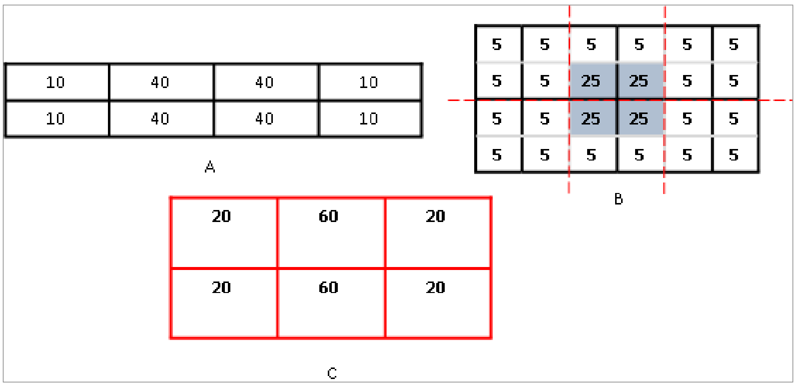

Figure 6-1: Illustrates the Modifiable Areal Unit Problem (MAUP) in terms of scale and zoning limitations. Diagram A shows scale problem by breaking down the aggregated areas into smaller unit shown in B; a highlighted cluster appears and changes the spatial pattern from A. Zoning limitation is shown when the units are aggregated into C by redefining the boundary according to the red lines shown in B.

5.5.2 ECOLOGICAL FALLACY

The second major limitation for the study was the ecological fallacy whereby associations found at aggregate level cannot be directly applied back to the individual level; it can only be applied speculatively (Lawson, Browne, & Rodeiro, 2003). This is because aggregating data changes existing individual-level associations. In the context of this study, associations found with respect to CAU-aggregated factors in Appendix B cannot evidently be applied back to individuals living within a CAU.

5.5.3 SIMPSONS PARADOX

Simpson's paradox may also have influenced the BYM modelling whereby results obtained by adding the CAU's together may reverse the result; if each of those CAUs are analysed individually. Consider the fictitious example shown on Table 6-2 within the context of this study. This example suggests that by observing the combined CAU column, that *low* pipe damage counts are associated with *high* E.*coli* counts. Thus, a bigger percentage of E.*coli* damage per WSM pipe damage in the combined CAU column. However, if you compare the count of E.*coli* between WSB and WSM pipes for each CAU, then it appears that the *high* pipe damage counts are in fact associated with *low* E.*coli* counts; a reversal of the first association. Thus Simpson's paradox can may have been present in the study especially when the CAU data was added according to Wards in Tables 4-2 and in Figures 4-9; and 4-10.

Table 6-1: A fictions example of Simpson's Paradox. The abbreviation CAU stands for Census Areal Unit—an area with a specified boundary, Escherichia *coli* (E.*coli*).

Count	CAU1	CAU2	Total (for combined CAUs)
Water Submain pipes damage count (WSB)	20	80	100
E.*coli* Count (MPN/100mL)	7	3	20
Percentage of E.*coli* counts for WSB pipe damage	35%	4%	**10%**
Water Main pipe damage count (WSM)	60	20	80
E.*coli* Count (MPN/100mL)	6	10	16
Percentage of E.*coli* counts for WSM for pipe damage	10%	50%	**20%**

5.5.4 DETECTION

Detection refers to the limited ability to detect data because of the method of data collection. Aggregating data per CAU limited data detection. This is because an aggregated damage count negated the following data characteristics: type of damage and the intensity of that damage for a factor. For instance, a wastewater (WW) damage count aggregated per CAU (inferred by repair damage) does not consider the type of pipe repair, such as sewer spillage or gravity pipe repair. Damage intensity also neglected E.*coli* concentration (per MPN/100mL) at a point location. For example, some point locations had 8 E.*coli* counts (MPN/100Ml), whilst other point locations had 2 E.*coli* counts (MPN/100mL). These point counts were generalised into a single count, and those individual counts were aggregated per CAU. Although aggregating the data helped in the application of spatial tests, it did contribute to information loss.

Lack of data limited this study, and collecting more data of better quality may have improved the results of this study. A particular example is the confirmed gastroenteritis cases used in this study. This means gastroenteritis cases are recorded when a symptomatic person goes to a health professional and takes the required laboratory tests. Under a post-disaster environment, most people may lack access to a health professional, not to mention the fact that health clinics themselves may not be operating because of earthquake damage. Moreover, gastroenteritis is short-lived (1-2 days on average) (Hall, 2004). Thus, people may not go to a health professional, but may transmit the infection to surrounding people. Hence, the confirmed gastroenteritis cases may be an underrepresentation for the study period of 35 days. Moreover, the study assumed the covariates were immutable; in reality, the opposite is true: covariates are time-sensitive because damages to infrastructure and liquefaction ground damage can be reduced or increased over time.

5.5.5 ADDITIONAL EXPLANATORY DATA

Both of the BYM Models suggested that factors included in models did not fully explain the spatial distribution of gastroenteritis prevalence and E.*coli* counts. This indicated that other factors needed to be included in the model to improve spatial explanation of the dependent variables. Additional factors are outlined in Figure 2-1. Some of those factors include socio-economic status; population mobility; high-risk people such as children and the elderly; subsequent events like aftershocks or heavy rain; and other pathogen sources such as contaminated food handling. One particular example that may have influenced the recorded gastroenteritis cases, which is not included in the model is the influence of contaminated rivers, which increases the exposure to possible gastroenteritis pathogens. Analysis conducted by ESR (2012b) identified that rivers—particularly the Avon River—had high E.*coli* counts in the river after the February 22, 2011 earthquake. Data unavailability prevented these factors to be included in the study, but the existing models can be expanded to include this factor with ease.

5.5.6 MULTICOLINEARITY

Another limitation that may have influenced BYM modelling was the effect of multicolinearity, to varying degrees. Formally, multicolinearity refers to high correlation between covariates in the regression analysis, which can lead to spurious results, and wide credible intervals (high uncertainty) (Berry & Feldman, 1985). Multicolinearity was evidenced in Spearman's Rho analysis, especially for earthquake-induced infrastructure damage and liquefaction ground damage. This indicates that some variables reflect the same information (a property of the data as opposed to data collection). It can also be considered that for BYM modelling that aggregated covariate factors (which were independently recorded) may have interacted with the dependent variable and within covariates either for a positive or negative effect for spatial analysis.

5.5.7 RECALL BIAS

Finally, recall bias was the third limitation pertaining to the qualitative component of this study. Recall bias stems from participants recalling inaccurate information from past exposure or experiences that can arise from the participants or the interviewer (Nieto & Szklo, 1999). This can be due to inexperience at asking or answering the interview questions or responding objectively. At the time of the interviews, it had been 18 months since the February 22, 2011 earthquake. Because of this time lapse, recall bias was a major potential factor, which could have impacted the findings of this research. Although this was not actively noticed, it cannot be excluded from the study. Furthermore, any conflicting responses were not included in primary coding of analysis to maintain data quality.

To minimise recall bias, a large sample size that was practically feasible within the time frame of this research (30 participants) for GT analysis was used. In doing so, the interview questions were repeated for clarity and confirmation. In addition, interviewer recall bias was eliminated by audio recording the interviews and taking supplementary notes during the interview. The interview analysis commenced by transcribing the audio-recordings.

5.5.8 ANCILLARY LIMITATIONS

Ancillary human errors may have acted as potential limitations for this study. These include incorrect data inputting to operate the WinBUGS14 model due to data quality, GIS handling errors as well as transcribing and interpretive errors. Notwithstanding such caveats, every precaution was taken to eliminate such limitations. It is also possible that the results derived from the interview participants represent their views and may not be a "complete picture," as indicated by Charmaz (2006). Despite this, the information learnt from this case study can be immensely useful for future lessons.

5.6 FUTURE WORK

Further research needs to be carried out to understand the "micro-level" effects of how earthquake-induced infrastructure damage can potentially influence gastroenteritis agents. This study has indicated an intimate coaction between infrastructure damage on one hand and E.*coli* and FAC-NC on the other. Previous work conducted by Gupta et al. (2007) and Swerdlow et al. (1992) has already indicated how pathogens can enter water network systems, but not in conjunction with liquefaction ground damage amid an earthquake. This needs to be further investigated using ArcMAP10.0 at the level of point data. More specifically at the micro-level, the mechanisms involved when water and wastewater pipes buried in liquefiable soil, "break" or "crack" during an earthquake need to be explored more in detail. When this occurs, do pipes disgorge their contents *out* to the surrounding area (exfiltration), or does material enter the pipe from the surrounding environment (infiltration)? Given that wastewater pipes are located below the water pipes, it is possible to consider the following scenario: during an earthquake, the water and wastewater pipes crack or break. Simultaneously, the soil is liquefied into a semi-liquid state. Hence, the wastewater pipe contents exfiltrate into the surrounding semi-liquid state, which contaminates the semi-liquid with wastewater contents; this, sewage-contaminated semi-liquid is bought to the surface via sand boils, or as sewage-contaminated liquefaction ejecta. In the end, the liquefaction ejecta can result in surface flooding over an area is contaminated with sewerage contents, which can now spread.

During this surfacing process, the semi-liquid contaminated with sewage must pass the water pipes, which may also be cracked, but still may be operating at reduced capacity. This indicates the following possibility: exfiltration of sewage-contaminated material can also disseminate through the water network as well as at surface level. Using the minimum solid wastewater guidelines, microbial estimates can be obtained for the volume liquefied material, (New Zealand Water and Waste Association [NZWWA], 2003). Thus, in the immediate aftermath of the earthquake a possible microbial count can be obtained for a unit area by treating the area as a surface flooding scenario. There are many avenues by which pathogens can disseminate, and the scenarios considered above can also be exacerbated by subsequent events such as rain.

Thus, deciphering the aforementioned scenario and applying the model in a post-disaster situation can aid emergency respondents. It enables emergency staff to get an approximation of general microbial concentration per unit area that is associated with common public health infections after a disaster, such as gastroenteritis, which in turn can identify possible public health issues. One particular application may be if an EC was to open near an area with sewage-contaminated surface flooding (due to liquefaction ejecta or lateral spreading). By understanding the possible intensity of microbial concentrations over an area, additional EC protocols can be established where needed. This can be an insidious situation if evacuees are entering ECs with sewage-contaminated footwear. One such protocol that can be to set up is sanitising footbaths. These are low cost to implement and maintain whilst an EC is open to the public. Footbaths can be incorporated into the EC layout at efficacious places such as the main entrance, or other "choke points" to prevent pathogen dissemination at ECs.

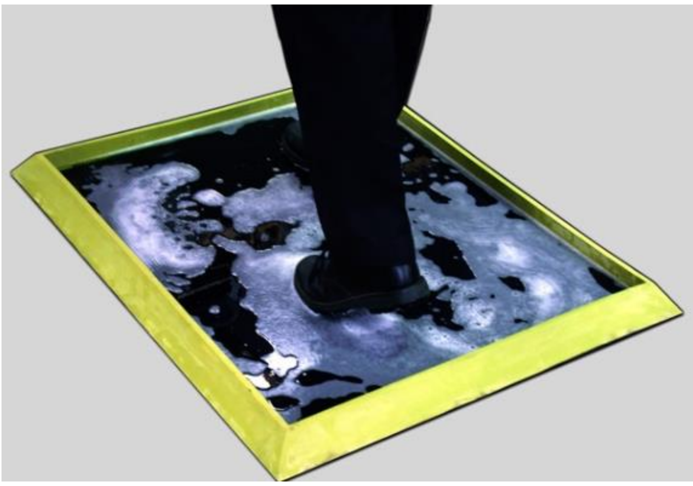

Figure 6-2: Diagram of a sanitising footbath.

CHAPTER 6: THESIS CONCLUSIONS

This multidisciplinary research was designed to assess whether the recorded gastroenteritis point prevalence recorded following the February 22, 2011 Christchurch earthquake could be spatially explained by earthquake-induced causative factors including liquefaction ground damage; earthquake-induced infrastructure damage; and the presence of gastroenteritis agents (non-compliant FAC and E.*coli)* in the drinking water network. A further aim of this study was to discover and analyse integral protocols that prevented gastroenteritis outbreaks at three Emergency Centres (ECs).

As a result of this study, an integrated database with a clear outline of gastroenteritis causative factors, and consequences following the Christchurch earthquake has been created. The study has also identified spatial associations of gastroenteritis agents with some success. The successful preventive protocols at ECs have been isolated, and translated into lessons learnt that could inform endemic infectious disease management plans.

In more details, the quantitative analysis was designed to assess whether the recorded gastroenteritis point prevalence could have been spatially explained by the following associated factors:

- The water network pipe damage count (main and submain pipes), whereby damage was represented as pipe bursts
- The wastewater network pipe damage count, which included array of different types of damage such as sewer mains and pipe cracks
- The liquefaction damage included lateral spreading and surface ejecta; henceforth, those damages will be termed collectively as liquefaction ground damage, which were represented as the percentage of the total per Census Area Unit (CAU)
- The levels of Free Associated Chlorine Non-Compliant (FAC-NC) (<0.02mg/L), which was the chlorine available to disinfect the drinking water supply; and, in this study, low levels of FAC-NC were considered as a gastroenteritis agent, because low FAC-NC levels in the water supply may enable pathogens to remain in the drinking water supply
- Escherichia *coli* (E.*coli*) are the pathogens present in the water supply (MPN/100mL) and considered as a gastroenteritis agent in this study.

Spatial associations were assessed using quantitative spatial and non-spatial statistical tests, whilst qualitative methods involved conducting interviews, and analysing them by applying the Grounded Theory (GT) approach (therefore, a mixed methods approach). For quantitative analysis, a damage profile table was created, which amalgamated the aforementioned associated factors for each CAU in the study area. Creating the damage profile table allowed to generate thematic maps and to conduct the following statistical tests: frequency distributions, Moran's *I*, Hot Spot Analysis (HS), Spearman's Rho and Besag–York–Mollié Model (BYM Model). The Spearman's Rho and BYM Models tested how the associated factors affected the outcome both spatially and non-spatially (Spearman's Rho), whilst the remaining tests were applied to each associated factor for spatial distribution analysis. The quantitative spatial analysis identified an apparent spatial clustering of gastroenteritis cases in Christchurch compared with cases found in the South Island, New Zealand over 35 days following the February 22, 2011 earthquake. A second spatial association showed a 14-fold increase in gastroenteritis cases in Christchurch compared with the same study period the year before. BYM modelling showed that the gastroenteritis point prevalence was best spatially explained by spatial distributions of E.*coli* counts (even though they were statistically non-significant). The E.*coli* spatial distribution was best explained by water, wastewater damage, and liquefaction ground damage and this spatial combination some statistical significance. However, the associated factors considered in this study did not explain the prevalence of gastroenteritis for all CAUs. This suggests that other factors are needed to fully explain the spatial variation of gastroenteritis prevalence and they can be CAU-specific. Moreover, Spearman's Rho analysis indicated that there was a weak and indirect association between gastroenteritis prevalence; and the following factors: water and wastewater network damage, liquefaction ground damage (lateral spread and surface ejecta); and FAC-NC. It was also found from thematic maps that the eastern sides of Christchurch had the greatest spatially aggregated counts of high damage per CAU for the considered factors. The research findings indicate that gastroenteritis prevalence is CAU-specific, and the results of this study can be used as a basis for identifying those factors specific to different CAUs.

The qualitative analysis addressing the second research question involved interviewing 30 participants from three Emergency Centres (ECs): Burnside High School (BEC), Cowles Stadium (CEC), and Linwood High School (LEC). There were no outbreaks of gastroenteritis recorded at the ECs following the February 22, 2011 earthquake. Despite populations that may have been exposed to E.*coli* sources, this did not translate into a gastroenteritis outbreak. This suggested that the implemented protocols may have successfully prevented such an outbreak. The analysis of those interviews using GT yielded two themes: direct and indirect. The direct themes were the prolific use of hand sanitisers, isolation room provisions, EC infrastructure services provided, and maintaining separate areas. The indirect themes included the EC layouts; lessons learnt; and staff dynamics that enabled implementation and maintenance of the active direct themes. Both direct and indirect themes were highly dependent on each other.

Understanding the link between direct and indirect themes from this research can increase awareness of how to prevent gastroenteritis outbreaks at ECs for both the EC organisers and public health officials, especially managing resources. For example, public health officers can identify effective hand sanitiser stations more strategically by understanding the EC layouts instigated by the EC staff members. Likewise, the EC staff members can be aware of the implications that adapting an EC layout that may have on direct themes. This interrelationship can be used during EC training sessions to highlight flow-on effects of the indirect themes on the direct themes. For example, establishing choke points not only manages foot traffic, but also is an excellent opportunity to locate hand sanitiser stations. Although the results may be limited by recall bias, albeit minimal, understanding of such protocols can provide crucial information. This information can serve as a resource to other ECs that may open as part of a post-disaster response.

Although many publications—such as IAVM (2005) and WHO (2005) — are available on the above-mentioned direct and indirect themes. Reviewing available literature indicated there is limited information on how the two themes interact harmoniously to prevent gastroenteritis outbreaks. This link has been investigated and analysed in this research. This research's outputs provides greater awareness of preventing gastroenteritis outbreaks at ECs, and the outputs could be potentially incorporated into the NZ national endemic plans and internationally.

Likewise, many studies have investigated gastroenteritis following earthquakes but very few studies that encompass geological changes (liquefaction ground damage), infrastructure (water and wastewater damage) and gastroenteritis agents (E.*coli* and FAC-NC) following an earthquake. Moreover, coupling quantitative with localised qualitative study further strengthens the approach to investigating gastroenteritis prevalence following a natural disaster. For example, the damage profile table can be adapted to create an integrated database of gastroenteritis consequences, hazards and exposure factors using the Figure 2-1. Additionally, this database can be used as disaster preparation and coupled with the questionnaire that has been used in the study to explore more vulnerable CAUs. Those vulnerable CAUs can be identified by implementing the integrated database into BYM modelling. Another area of possible future research can be developing a surface microbial model from sewage-contaminated liquefaction ground damage following an earthquake. Consequently, following a major earthquake, where liquefaction ground damage is mostly seen as surface flooding, the microbial model can indicate pathogen concentration from a “worst case” scenario, which can inform emergency responders to allocate resources accordingly.

In summary, this research analysed post-earthquake infectious diseases using a methodology for visualising data by creating a damage profile that was specific to a CAU, and then coupling this information with local qualitative data from EC staff. Using this approach enabled to investigate the correlation between gastroenteritis point prevalence, and associated factors. In addition, this study has also isolated mitigative protocols that were implemented at the three ECs. This research has collectively provided an insight into the intractable nature of gastroenteritis prevalence following an earthquake. Improvements for the mixed methods approach include extending the scale of the methodology to incorporate more data into the profile table and the BYM model. Thus, this research forms the stepping-stone for amalgamating qualitative and quantitative data to study infectious diseases in a post-disaster context; and it can inform the current infectious disease management plans following a disaster in New Zealand. Moreover, the preventive protocols identified can serve as guidelines to prevent gastroenteritis prevalence at an EC during a disaster response in New Zealand and globally.

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APPENDIX A: The Study Area

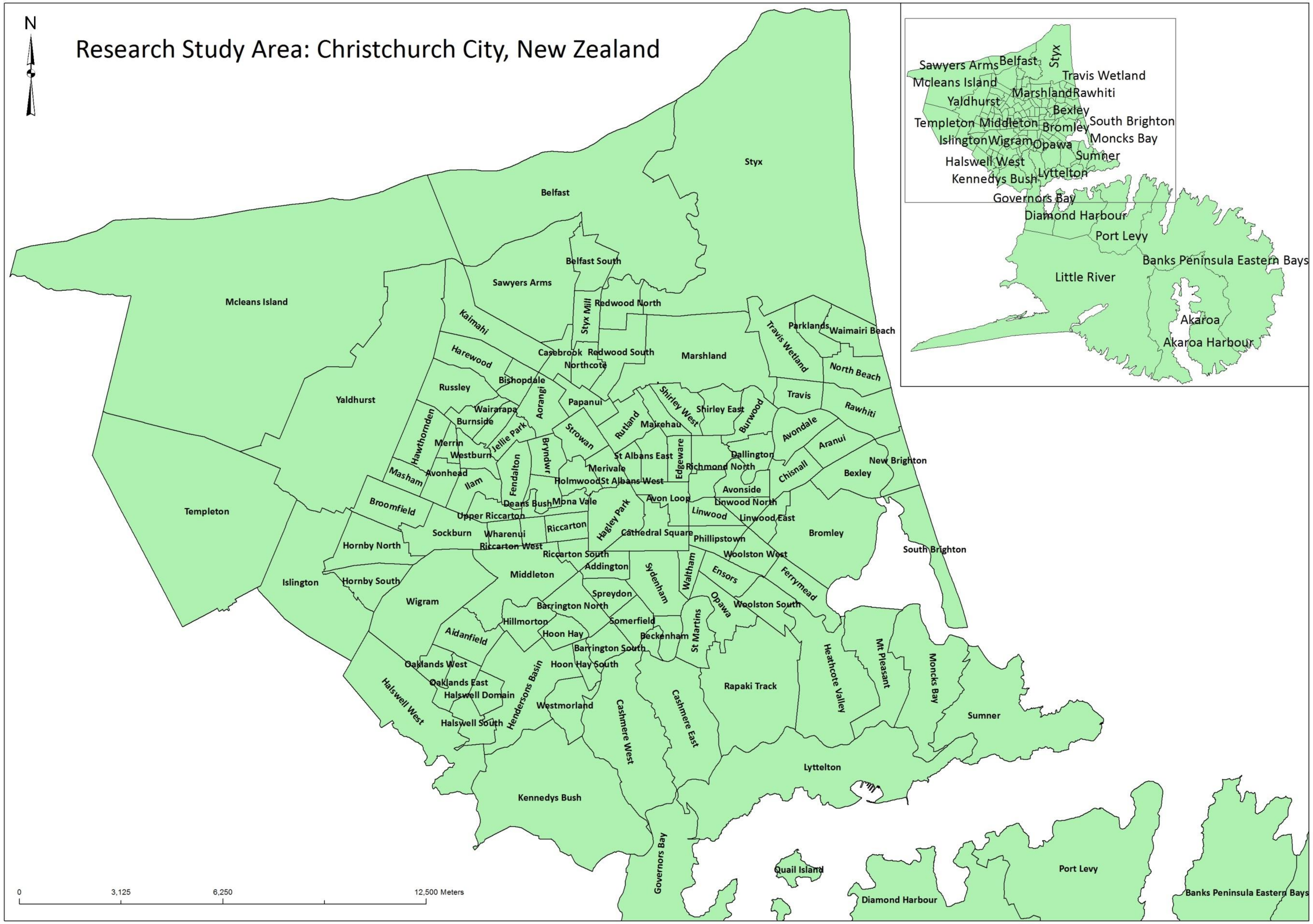


Figure A- 1: illustrates Christchurch city: the study area considered for this research.

APPENDIX B: Summary of Variables Considered for Quantitative Analysis

Table B-1: Summary of data collated for quantitative analysis outlining the recorded gastroenteritis cases.

	Data Name	Data Type in Shapefile Format for ArcGIS10.0	Date Range in which data was collected	Comments
Gastroenteritis cases and Gastroenteritis causative agents	Escherichia coli (E.*coli*) Transgression (RESPONSE FACTOR)	Point	24/2/2011-17/6/2011	E.*coli* Transgressions means that minimum allowable number of E.*coli* has been detected in water samples. Tested samples were collected from restored water supply after the February 22, 2012 earthquake (Dell et al, 2012). Each data point contains a value between 0-16 in MPN*/100mL. Collected water samples were tested at Canterbury Health Laboratories and Waimakariri District Council (Dell et al, 2012). MPN refers to Most Probable Number of E.*coli* is used as an indicator organism for possible human and animal excrement (MPN/100mL). The data was sourced from Canterbury District Health Board, New Zealand.
	Free Associated Chlorine (FAC) Or Free Available Chlorine (Non-Compliant)	Point	26/2/2011-24/4/2011	All point data was non-compliant (value less than 0.20mg/L). FAC is the Hypochlorous acid and hypochlorite ion concentration present in chlorinated water (NZ Drinking Water Standards, 2008). It is the residual chlorine concentration present in the water for disinfection. FAC must be at least 0.2mg/L within the water distribution system to reduce Coliform bacteria to insignificant levels (Ministry of Health, 2008). Concentration below this level was deemed non-compliant. All point data has a value less than 0.20 mg/L. The data was sourced from Canterbury District Health Board, New Zealand.
	Acute Gastroenteritis cases	Aggregated count (per CAU)	22/2/2010-28/3/2010 22/2/2011 – 28/3/2011	Number of confirmed acute gastroenteritis cases notified to Environmental Science & Research (ESR) Limited New Zealand, per CAU for South Island and Christchurch. Obtained acute gastroenteritis cases did not name infection agent origin. The data was sourced (ESR).The criteria for which acute gastroenteritis cases notified to ESR are outlined in the following document by Ministry of Health, New Zealand: Ministry of Health, New Zealand, MOH. (2012). Communicable Disease Control Manual 2012. Wellington: Ministry of Health. ISBN 978-0-478-36622-8.

Table B-2: Summary of data collated for quantitative analysis outlining the Water and Wastewater Network Damage repairs.

	Data Name	Data Type in Shapefile Format for ArcMap10.0	Date Range in which data was collected	Comments
Water and Wastewater Network Damage Repairs	Portable Water Network Mains Pipes	Point	23/2/11-11/6/2011	Point locations of water repairs: locations are based on repair addresses with some errors in locations. Damage occurrence is closely linked to earthquake events as evidenced by job creation dates within the shapefile. The data was sourced from Stronger Christchurch Infrastructure Rebuild Team (SCIRT).
	Portable Water Network Submain Pipes	Point	23/2/11-11/6/2011	Point locations of water repairs: locations are based on repair addresses with some errors in locations. Damage occurrence is closely linked to earthquake events as evidenced by job creation dates within the shapefile. The data was sourced from Stronger Christchurch Infrastructure Rebuild Team (SCIRT).
	Wastewater Network Pipe Damage	Point	25/2/2011-21/9/2012	Point locations of wastewater repairs: locations are based on repair addresses with some errors in locations. Damage to wastewater pipes were closely linked to earthquake events. This is because wastewater infrastructure is buried 4-8m below soil surface; hence, damage was invisible from the ground surface. Nonetheless damage had occurred which was exacerbated following the February 22, 2011 earthquake. The data and information was sourced from Stronger Christchurch Infrastructure Rebuild Team (SCIRT).

Table B-3: Summary of data collated for quantitative analysis outlining the earthquake factors and population characteristics.

	Data Name	Data Type in Shape file Format for ArcGIS10.0	Date Range in which data was collected	Comments
Earthquake Factor	Liquefaction	Polygon	22/2/2011-22/2/2011	Road scale maps or residential properties showing various categories (Figure B-1) of ejected material and lateral spreading that was visible at the surface following the February 22, 2011 earthquake. The data was sourced from: Geotechnical Database (2013) "Liquefaction and Lateral Spreading Observations", Map Layer CGD0300 - 11 Feb 2013, retrieved July 2012
Population Characteristics	Census Area Unit (CAU)	Polygon	Data from 2006 Census, New Zealand (NZ).	A Census Area Unit (CAU) is amalgamated meshblocks with a single geographical entity with a unique name, such as a suburb name. Meshblock is the smallest geographic unit where data is collated by Statistics New Zealand. The data was sourced from Statistics New Zealand: www.stats.govt.nz/tools_and_services/nzdotstat/2006-census-pop-dwellings-tables.aspx
	Population	Polygon	Christchurch CAU in 2006 New Zealand Census	Number of People screened at night, thereby assumed to be living in the Census Area Unit. (Number of people screen at night) (Statistics, NZ) Website: www.stats.govt.nz/tools_and_services/nzdotstat/2006-census-pop-dwellings-tables.aspx

APPENDIX C: Liquefaction and Lateral Spreading Observations

4 Sep 2010 - Property Observations

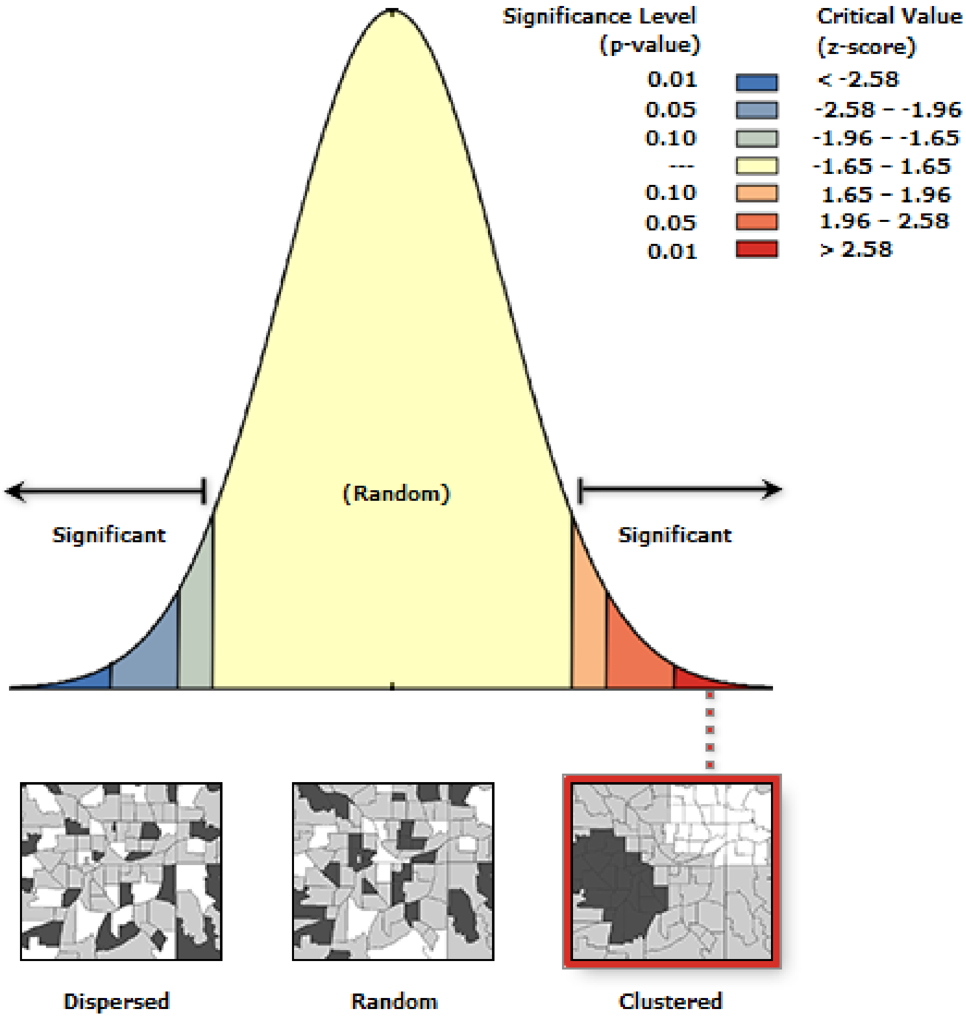
Land Observation Category	Criteria / Description
Blue	• No observed cracks, undulations / deformations at the ground surface, and, • No signs of ejected liquefied material at the ground surface, and, • No apparent lateral movement.
Green	• Shaking-induced damage resulting from cyclic deformation and surface-waves causing ground surface damage. Ground surface damage likely limited to minor cracking (tension) and buckling (compression) and/or minor undulations at the ground surface, and, • No signs of ejected liquefied material at the ground surface, and, • No apparent lateral movement.
Light Orange	• Minor to moderate quantities of ejected liquefied material on ground surface (generally <25% of site covered with ejected material), and/or, • Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, • No apparent lateral movement.
Red	Either • Large quantities of ejected liquefied material on ground surface (generally >25% of the site covered with ejected material), and/or, • Severe observed ground surface subsidence, and/or; • Small cracks from ground oscillations (<50 mm) may be present, but little to no vertical displacement across cracks, and, • Limited evidence of lateral movement. or • Moderate to major lateral spreading (<1 m cumulative), and/or, • Large cracks extending across the ground surface, with horizontal and/or vertical displacement (>50 mm, but generally <200 mm). • Ejection of liquefied material at the ground surface may also be observed
Dark Red	• Extensive lateral spreading (=1 m cumulative), and/or, • Large open cracks extending through the ground surface, with very severe horizontal and/or vertical displacements (=200 mm), and, • Ejection of liquefied material at the ground surface may also be observed.

Figure C-1: Graded liquefaction damage for private properties after the February 22 2011 earthquake. "Geotechnical Database (2013) "Liquefaction and Lateral Spreading Observations", Map Layer CGD0300 - 11 Feb 2013, retrieved July 2012 .

Important notice

Figures 4-3, 4-5, 4-7, 4-8, 4-10, Table 4-1 and Table 4-2 were created from maps and/or data extracted from the Canterbury Geotechnical Database (https://canterburygeotechnicaldatabase.projectorbit.com), which were prepared and/or compiled for the Earthquake Commission (EQC) to assist in assessing insurance claims made under the Earthquake Commission Act 1993. The source maps and data were not intended for any other purpose. EQC and its engineers, Tonkin & Taylor, have no liability for any use of the maps and data or for the consequences of any person relying on them in any way. This "Important notice" must be reproduced wherever Figures 4-3, 4-5, 4-7, 4-8, 4-10, Table 4-1, and Table 4-2 or any derivatives are reproduced.

APPENDIX D: Normal Probability Distribution and Clustering Patters using Spatial Autocorrelation operation in ArcMap10.0



z-score or standard deviation	p-value	Confidence interval
<-1.65 or > +1.65	<0.10	90%
<-1.96 or > +1.96	<0.05	95%
<-2.58 or > +2.58	<0.01	99%

Figure D-1: Table above informs how the normal distribution curve, z-score, p-value and confidence intervals. The figure shows the table's relation to the clustering pattern (dispersed, random, and clustered) using Moran's I index. Dispersed pattern reflects the blue shades, the normal pattern is shown by the yellow and the orange to red shades refers to a clustered pattern. The figure was sourced from (ESRI, 2013)

APPENDIX E: WinBUGS14 Model

WinBUGS14 Code used for the Besag–York–Mollié Model (BYM Model).

Model 1

```
model
{
  for (i in 1 : N) {
     GAST[i]  ~ dpois(mu[i])
      log(mu[i]) <- log(E[i]) + a0 +  a1 * WSB[i] + a2 * WSM[i] + a3 * WW[i]  + a4 * FAC-NC[i] + a5 *
LIQ[i] + a6 * Ec[i] +b[i]
      RR[i] <- exp( a0 + a1  * WSB[i] + a2 * WSM[i] + a3 * WW[i] + a6 * EC[i] +b[i])   # Area-specific
relative risk (for maps)
  }

  # CAR prior distribution for random effects:
  b[1:N] ~ car.normal(adj[], weights[], num[], tau)
  for(k in 1:sumNumNeigh) {
      weights[k] <- 1
  }
  # Other priors:
  a0  ~ dflat()
  a1 ~ dnorm(0.0, 1.0E-5)
  a2 ~ dnorm(0.0, 1.0E-5)
  a3 ~ dnorm(0.0, 1.0E-5)
  #a4 ~ dnorm(0.0, 1.0E-5)
 #a5 ~ dnorm(0.0, 1.0E-5)
  a6 ~ dnorm(0.0, 1.0E-5)
  tau  ~ dgamma(0.5, 0.0005)     # prior on precision
  sigma <- sqrt(1 / tau)                    # standard deviation
}
#INITS
list(tau=1, a1=0,a2=0,a3=0,a6=0,a0=0,
b=c(0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,
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0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0))
```

WinBUGS14 Programme Citation: Lunn, D.J., Thomas, A., Best, N., and Spiegelhalter, D. (2000) WinBUGS -- a Bayesian modelling framework: concepts, structure, and extensibility. *Statistics and Computing*, **10**:325--337.

WinBUGS14. Code used for the Besag–York–Mollié Model (BYM Model). Model 2

```
model
{
  for (i in 1 : N) {
     ECM[i]  ~ dpois(mu[i])
      log(mu[i]) <- log(E[i]) + a0 +  a1 * WSB[i] + a2 * WSM[i] + a3 * WW[i] + a4 * FAC-NC[i] + a5 *
LIQ[i] +b[i]
      RR[i] <- exp( a0 + a1  * WSB[i] + a2 * WSM[i] + a3 * WW[i] + a4 * FAC-NC[i] + a5 * LIQ[i]  +b[i])
# Area-specific relative risk (for maps)
  }

  # CAR prior distribution for random effects:
  b[1:N] ~ car.normal(adj[], weights[], num[], tau)
  for(k in 1:sumNumNeigh) {
      weights[k] <- 1
  }

  # Other priors:
  a0  ~ dflat()
  a1 ~ dnorm(0.0, 1.0E-5)
  a2 ~ dnorm(0.0, 1.0E-5)
  a3 ~ dnorm(0.0, 1.0E-5)
  a4 ~ dnorm(0.0, 1.0E-5)
  a5 ~ dnorm(0.0, 1.0E-5)

  tau  ~ dgamma(0.5, 0.0005)     # prior on precision
  sigma <- sqrt(1 / tau)                    # standard deviation
}

#INITS
list(tau=1, a1=0,a2=0,a3=0,a4=0,a5=0,,a0=0,
b=c(0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,
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0,0,0,0,0,0,0,0,0,0,0,0,
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0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0))
```

WinBUGS Programme Citation: Lunn, D.J., Thomas, A., Best, N., and Spiegelhalter, D. (2000) WinBUGS -- a Bayesian modelling framework: concepts, structure, and extensibility. *Statistics and Computing*, **10**:325--337.

APPENDIX F: Winbugs 14 Model Combinations

Table F-1: The combination of variables used as covariates for analysis on WinBUGS14. The highlighted squares were the factors that were included in each combination model.

	Explanatory Factors Considered for WinBUGS14 Modelling						
Combination Number	**Water Main**	**Water Submain**	**Lique -faction**	**Waste water**	**FAC**	**E.coli**	**Investigation Purpose**
Model 1: OBSERVED GASTROENTERITIS CASES EXPLAINED BY FACTOR COMBINATIONS BELOW $\log \mu_i = \log GAST_i + a0 + a1WSB_i + a2WSM_i + a3WW_i + a4FAC - NC_i + a5LIQ_i + a6Ec + b_i$							
C1							If observed gastroenteritis cases were due to water and wastewater network damage.
C2							Presence of E.*coli* explains observed gastroenteritis cases.
C3							Observed gastroenteritis cases are influenced by FAC-NC and E.*coli* only.
C4							Gastroenteritis cases are influenced by infrastructure damage (water and wastewater network damage) and presence of FAC-NC and E.*coli* in the drinking water system.
C5							If gastroenteritis cases were because of damages from wastewater and water and liquefaction with the presence of E.*coli* and FAC-NC in the drinking water system.
MODEL 2: OBSERVED E.COLI COUNTS EXPLAINED BY FACTOR COMBINATIONS BELOW $\log \mu_i = \log Ec_i + a0 + a1WSB_i + a2WSM_i + a3WW_i + a4FAC - NC_i + a5LIQ_i + b_i$							
C6							E.*coli* presence was explained by water and wastewater damage.
C7							If E.*coli* was a resultant of water pipe damage and liquefaction only.

Table F-2: Factor combinations of variables used as covariates for analysis on WinBUGS14. The highlighted squares were the factors that were included in each combination model.

	Explanatory Factors Considered for WinBUGS14 Modelling						
Combination Number	**Water Main**	**Water Submain**	**Lique -faction**	**Waste water**	**FAC**	**E.coli**	**Investigation Purpose**
MODEL 2: OBSERVED E.COLI COUNTS EXPLAINED BY FACTOR COMBINATIONS BELOW $\log \mu_i = \log Ec_i + a0 + a1WSB_i + a2WSM_i + a3WW_i + a4FAC - NC_i + a5LIQ_i + b_i$							
C8							If E.*coli* was due to water pipe damage and FAC. Places that were had severe water pipe damage and not able to chlorinate water properly.
C9							If E.*coli* was due to water pipe damage, and liquefaction only (not able to chlorinate due to liquefaction damage as well).
C10							E.*coli* count was not a direct result of liquefaction. It drew the idea that other things were present to contribute to E.coli count other than infrastructure damage. Compare results between 15 and 12.
C11							E.*coli* count was combination of water, wastewater and liquefaction.
C12							All factors were spatially associated with E.*coli* count in drinking water.

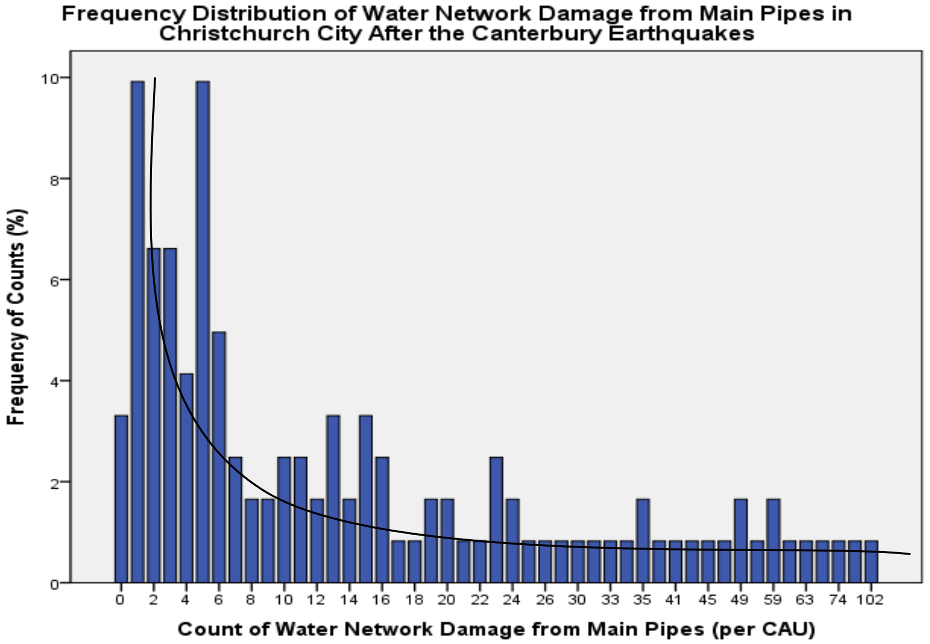
APPENDIX G: Interview Questionnaire

The questionnaire included a brief introduction to outline its purpose and the usefulness of the results in New Zealand's context. More importantly, the introductions explained the questions were designed for the two earthquakes (September 4 2010 and February 22 2011), which henceforth will be referred to as the Canterbury Earthquakes. The questionnaire was designed to guide participants to respond to the questions one category at a time. Each category comprised of questions that required descriptive answers and those requiring short answers. Therefore, beginning with volunteer details established channels of communication and provided a road map for proceeding questions such as essential lifeline services. Adopting this format avoided repetition and provided a semi-constructed interview in which the questionnaire acted as a guide only. Consequently, certain questions were answered comprehensively to suit participants' experiences and job roles.

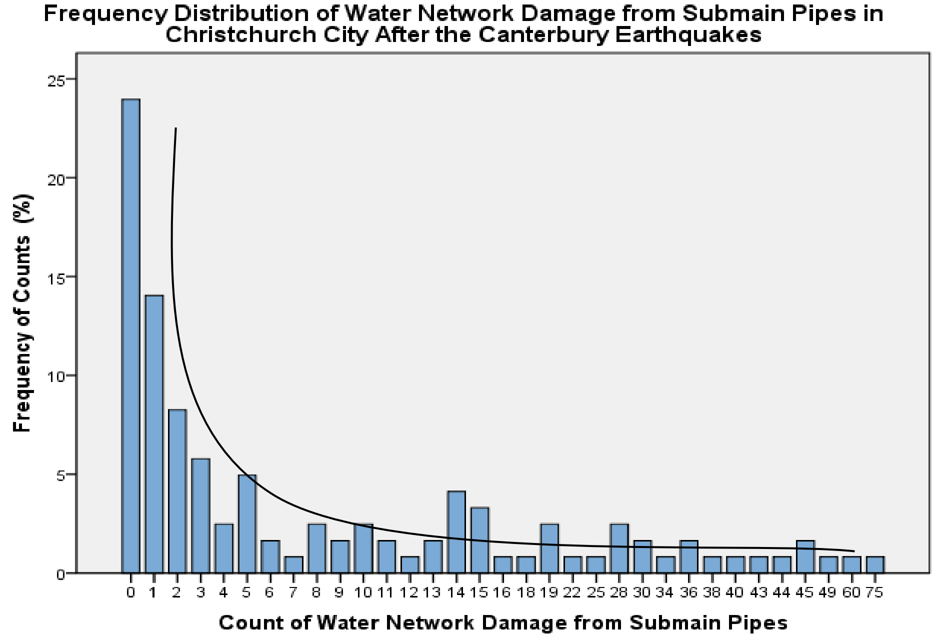
Components Attached to CD

- Interview participation letter
- Interview Information Sheet
- Interview Consent Form
- Interview Questionnaire

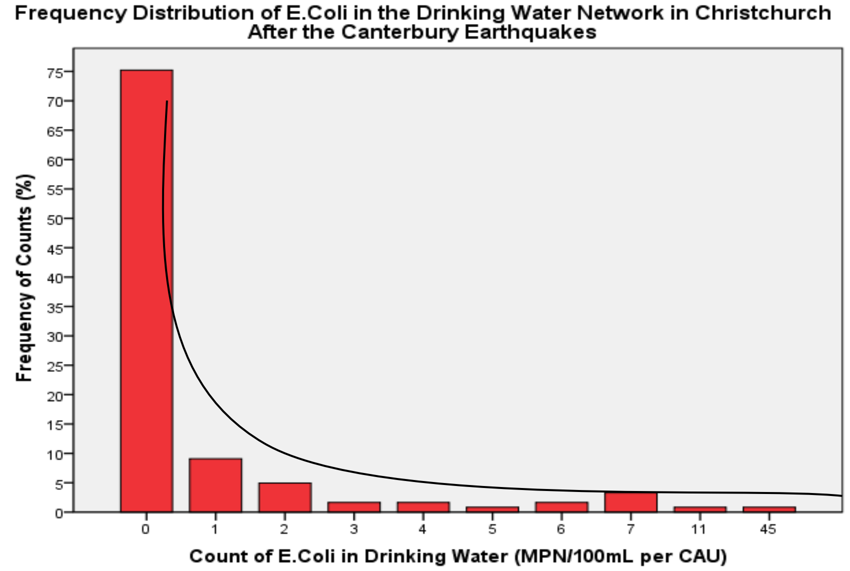
APPENDIX H: Frequency Distributions



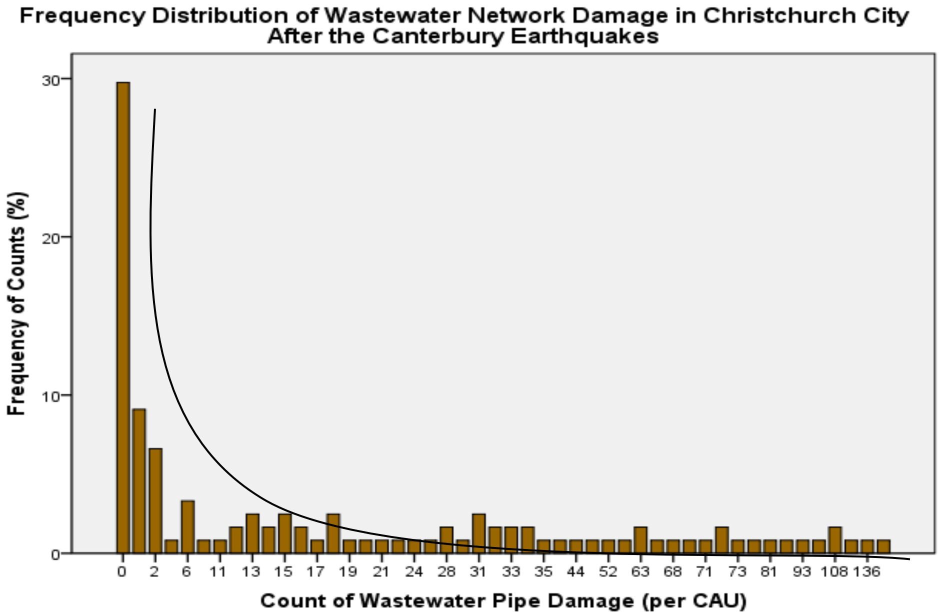
A



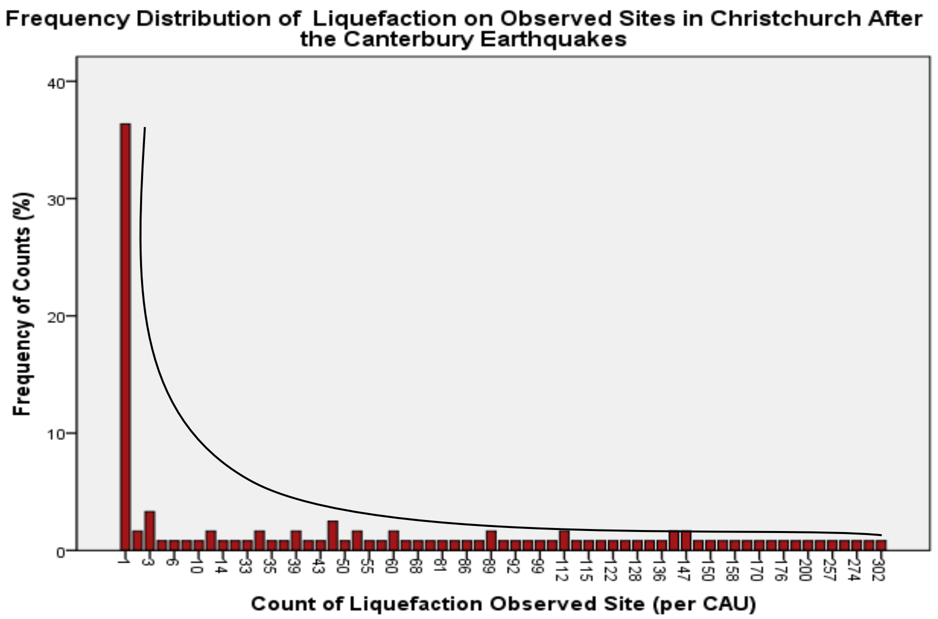
B



E



C



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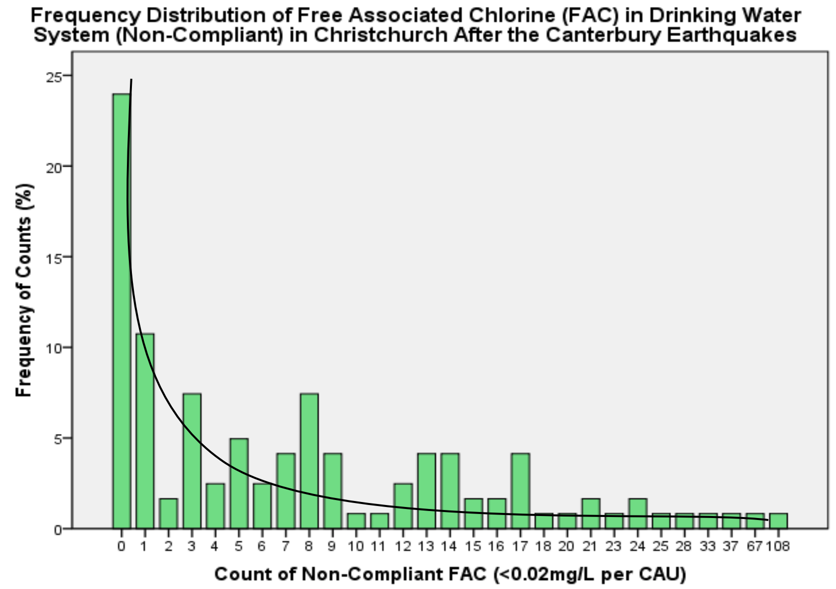

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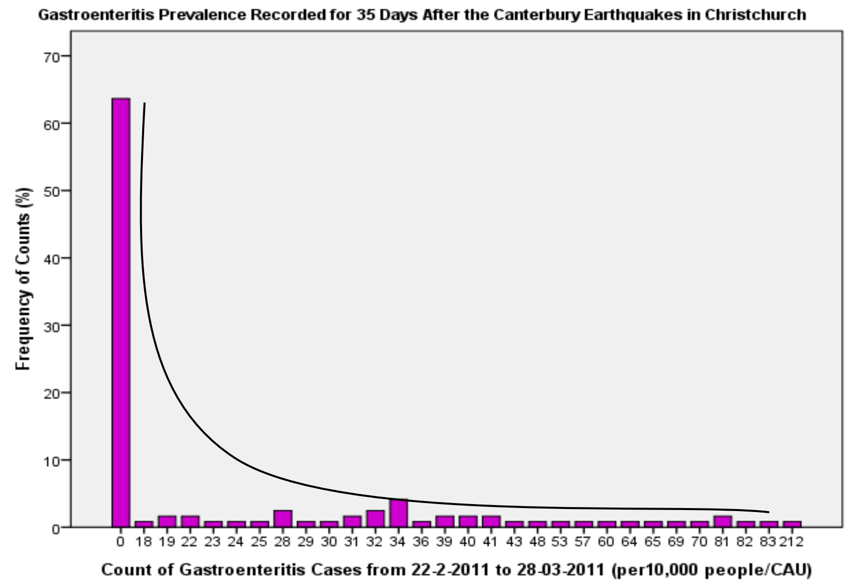

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Figure H-1: Frequency Distributions for factors considered for spatial modelling. All figures illustrate a power-law distribution.

APPENDIX I: Spearman's Rho Results in Matrix Form

Table I-1: Spearman's Rho results.

		E.coli Count in Drinking Water Taps (MPN/100mL)	Free Associated Chlorine (FAC) Non-Compliant (<0.02mg/L) Count	Number of Gastroenteritis Cases Between 22/2/2011-28/3/2011	Water Damage-Main Pipes	Water Damage-Submain Pipes	Wastewater Pipe Damage	Percentage of Area of CAU that was liquefied
E.coli Count in Drinking Water Taps (MPN/100mL)	Correlation Coefficient	1.000	**.386****	.143	**.339****	**.293****	**.256****	**.294****
	Sig. (2-tailed)	.	.000	.117	.000	.001	.005	.001
Free Associated Chlorine (FAC) Non-Compliant (<0.02mg/L) Count	Correlation Coefficient	.386**	1.000	**.332****	**.697****	**.730****	**.732****	**.620****
	Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000
Number of Gastroenteritis Cases Between 22/2/11-28/3/11 (Post-February Earthquake)	Correlation Coefficient	.143	.332**	1.000	**.280****	**.309****	**.271****	**.310****
	Sig. (2-tailed)	.117	.000	.	.002	.001	.003	.001
Water Damage- Main Pipes	Correlation Coefficient	.339**	.697**	.280**	1.000	**.782****	**.788****	**.640****
	Sig. (2-tailed)	.000	.000	.002	.	.000	.000	.000
Water Damage- Submain Pipes	Correlation Coefficient	.293**	.730**	.309**	.782**	1.000	**.842****	**.676****
	Sig. (2-tailed)	.001	.000	.001	.000	.	.000	.000
Wastewater Pipe Damage	Correlation Coefficient	.256**	.732**	.271**	.788**	.842**	1.000	**.817****
	Sig. (2-tailed)	.005	.000	.003	.000	.000	.	.000
Percentage of Area of CAU that was liquefied	Correlation Coefficient	.294**	.620**	.310**	.640**	.676**	.817**	1.000
	Sig. (2-tailed)	.001	.000	.001	.000	.000	.000	.

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX J: Moran's *I* Test Results
(Using Spatial Autocorrelation Operation in ArcMap 10)

Table J-1: Moran's *I* index for gastroenteritis prevalence, infrastructure damage; liquefaction and gastroenteritis causative agents (FAC and E.coli) after the February 22, 2011 earthquake. A z-score > 1.65 with a p value range from 0.10 to 0.01 indicate a clustered spatial pattern. A dispersed spatial pattern is indicated when the z-score is <-1.96 (with corresponding p-values of 0.10 to 0.01). A random spatial pattern is denoted with a z-score between -165 to 1.65 (p-value=0.10). Moran's Index (*I*) range from -1 to +1. When *I* <1 dispersed pattern; *I*=0 random pattern; and when *I* >1 clustered pattern. All factors showed clustered spatial patterns. All factors were clustered.

Variables Tested for Spatial Autocorrelation on ArcMap10.0		Moran's *I* Index (-1 to +1) (2dp)	z-SCORE (2dp)	p-VALUE (2dp)	Spatial Pattern (Dispersed, Random, Clustered)
Gastroenteritis Exposure Risk Factors	E.coli	0.015	1.90	0.058	Clustered
	Free Associated Chlorine (FAC-NC)	0.12	7.07	0.00	Clustered
	Gastroenteritis Cases per 10000 people	0.05	5.55	0.00	Clustered
Damage Counts from Infrastructure and Earthquake Factors	Water Network Damage-Main Pipes	0.26	13.026	0.00	Clustered
	Water Network Damage-Submain Pipes	0.21	10.59	0.00	Clustered
	Wastewater Network Damage	0.21	10.74	0.0	Clustered
	Liquefaction	0.23	11.48	0.0	Clustered

APPENDIX K: Moran's *I* Results for Besag–York–Mollié Model (BYM Model)

Table K-1: Spatial Autocorrelation of WinBUGS residuals from E.coli risk maps. Z-scores greater than 2.58, which reflect a low p-value, are statistically significant.

Combination Number	**Factors included**	**Moran's *I* Index (-1 to +1) (2dp)**	**z-SCORE (2dp)**	**p-VALUE (2dp)**	**Spatial Pattern (Dispersed, Random, Clustered)**
C2	**GAST=EC**	**0.23**	**23.36**	**0.00**	**Clustered**
C9	**EC=W+FAC-NC**	**0.09**	**9.26**	**0.00**	**Clustered**
C11	**EC=W+WW+L**	**0.04**	**4.40**	**0.000011**	**Clustered**

APPENDIX L: Emergency Centre Leadership Structure

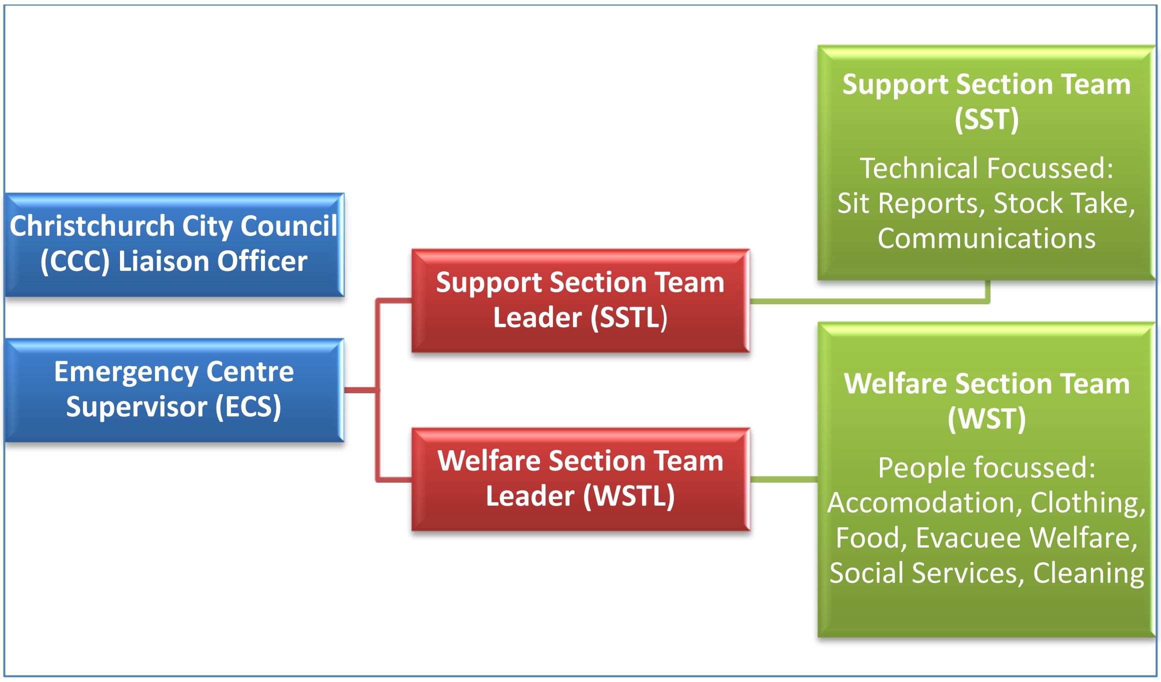


Figure L-1: The hierarchical structure of an Emergency Centre (EC) after the Christchurch February 22, 2011 earthquake. The top tier of an EC are ECS and Christchurch City Council (CCC) Liaison Officer who works together to oversee EC operations. The liaison officer operates with the CCC to free resources required by the EC. The support section is involved with technical aspects of the EC such as operating communications with the emergency operations centre, which oversee regional emergency response. The welfare section attends rest of the matters: everything to do with people aspects such as accommodation.

APPENDIX M: Emergency Centre Raw Results for Linwood High School Emergency Centre

LINWOOD HIGH SCHOOL EMERGENCY CENTRE (LEC): LAYOUT OVERVIEW

LEC had and a single main entry and exit that was guarded by professional security at all times. The evacuees would enter LECs main entry, a pedestrian walkway, and approach reception (Figure M-1). Security staff ensured that people entering the LEC approached reception first for traffic management. Approaching reception was mandatory for everyone—staff, volunteers, and evacuees. In following this procedure, LEC had an inventory of everyone housed at LEC for security, health and safety reasons.

At reception, CD staff would assess evacuees' needs and requests. If evacuees required services at LEC, they were advised to approach registration (Figure M-1 and M-2). At registration staff recorded the required services in a Red Cross Form (per family). A Red Cross form acted as a "permission slip" to access services. From registration evacuees may seek specific services needed. Initial LEC layout, designed before the earthquakes did not change once LEC was open to the public.

LINWOOD HIGH SCHOOL LAYOUT: INFRASTRUCTURE

From the outset, water, power and sewerage facilities were available on the first day at LEC. It took 2-3 days for social services to get established at LEC because during those initial days, LEC was figuring what out particular services were needed at LEC. Some of the first core services to get instigated were NZ Police, Work and Income and St Johns Ambulance service. In particular, NZ police helped to identify suspicious characters such as paedophiles. LEC staff also provided security services for the first 2-3 days but heightened by incorporating professional security guards in the coming days. Of most importance, security created a "presence" to reassure distressed evacuees and protected the cordon for isolated areas. A particular example, security had to deal at LEC was to patrol the water tank, where it was found that a person refilled water from the LEC water tank and sold it to the public nearby.

LINWOOD HIGH SCHOOL LAYOUT: SERVICES AND MEALS

A particular service, meal times were exploited by the public when LEC first opened to the public- predominantly because the meals were 'simply delicious". Initially, LEC did not require a Red Cross form to attend meal times. This instigated a large discrepancy of people requiring meals. Number of people arriving for meals was greater than the number of people registered. It was found out that "bystanders" were using the meal service intended for evacuees at LEC. As a result some EC staff and evacuees missed out on meal. To rectify, a mandatory rule was put in place: the entrance to the dining area had security staff whereby a person requiring meals must present a completed Red Cross form. This identified a registered evacuee; not a bystander. Because security could identify EC staff members, Red Cross form was necessary. Meal times were co-ordinated in groups where the first 100 people were invited for meals followed by the next 100 people and so on.

LINWOOD HIGH SCHOOL LAYOUT: STAFF

LEC staff trained together as a team for years: staff knew team members' personalities, strengths and weakness and supported each other to build a cohesive team environment. Hence, LEC staff had synchronised team dynamics. Combination of loyalty to forge ahead, adrenaline, and the immense workload meant some staff required persistence to relive of their duties. LEC had 40-45 staff working an average 12-hour shift for 3-4 days with many of the shifts feeling "like a long exercise." Eventually, staff fatigue emerged; followed by reports of diarrhoea illness among staff on day five (Table M-1). Consequently staff rosters were established: an eight- hour shift per day with no more than five continuous shifts per week that ultimately gave staff rest.

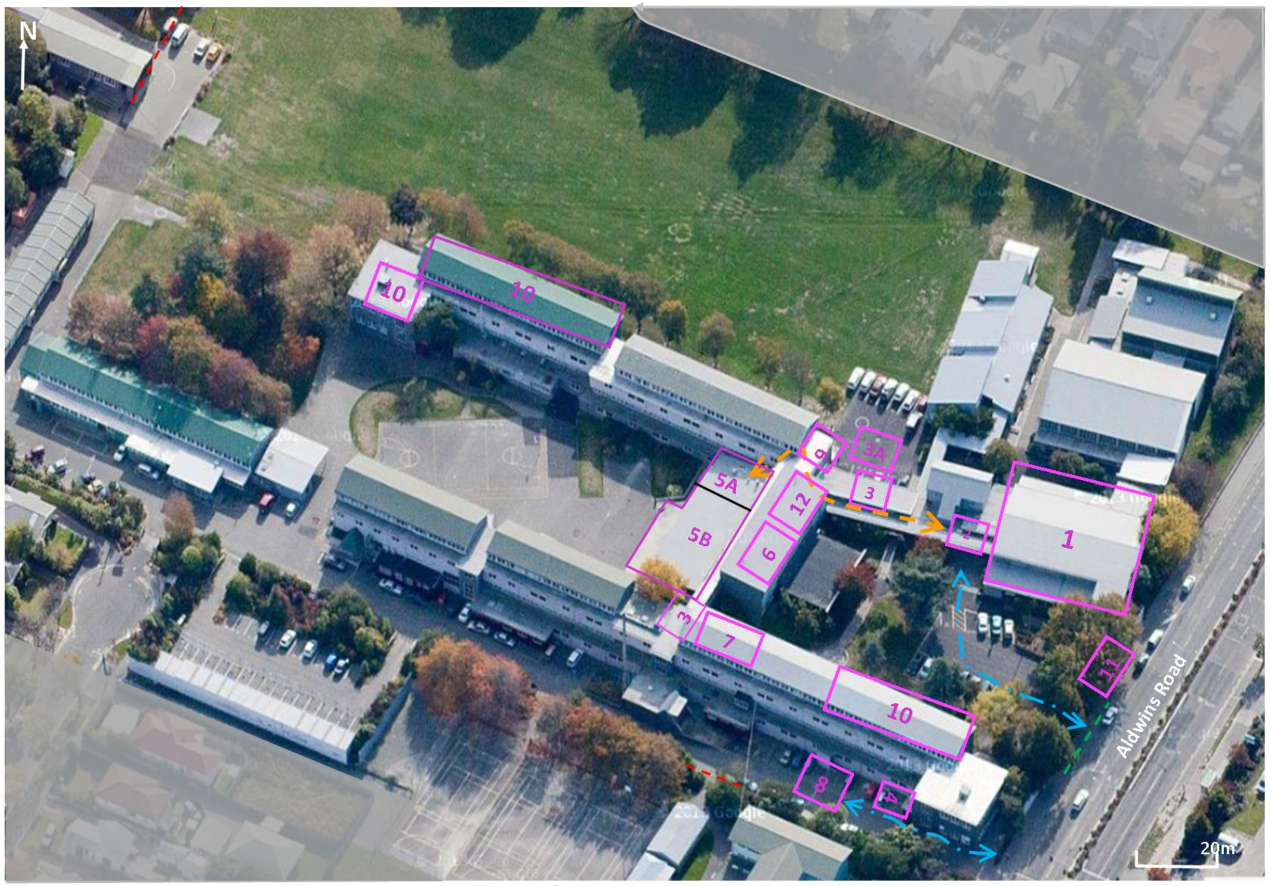
To compensate for resting staff, Coastguard Canterbury (CG) volunteers' were called in as additional staff to run the LEC. Coastguard volunteers complemented the existing LEC staff team because of Coordinated Incident Management System (CIMS) training command structure, and for their routine practices in emergency scenarios. The Coastguard team "moulded" into EC staff duties. They also contributed to improve the existing LEC management at the time such as implementing fire drills.

LINWOOD HIGH SCHOOL LAYOUT: HYGIENE

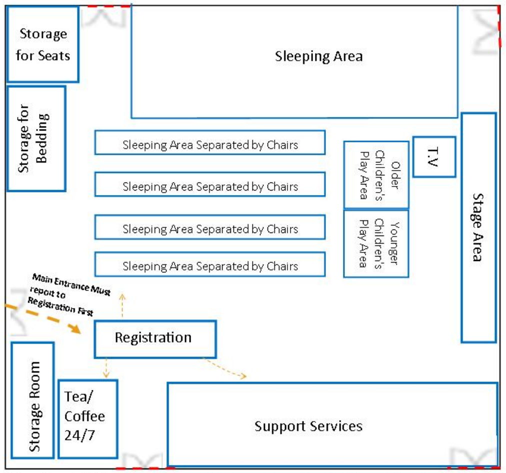
The first couple of days when the volume of evacuees coming into the LEC increased, effort to maintain adequate hygiene levels especially in the sleeping area and lavatories were grossly underestimated. EC staff was underequipped "we couldn't keep up; we didn't have the gear for it". Once professional cleaners were on site and coupled with volunteer organisations the hygiene levels immensely improved. Similarly, at the outset LEC had insufficient amount of hand sanitisers, which was rectified on the second day. Henceforth, every door entrance had a person (whether an evacuee or staff) with a hand sanitisers asking passing people to sanitise their hands. This process was heightened during meal times: no entry into the dining room without using hand sanitisers.

Initially personal food items (such as baby food, yoghurt) were permitted inside LEC. But as days progressed this was heavily discouraged to abate contamination risk, unless for personal dietary requirements (e.g. gluten free diet). Some contaminant risks people exposed to were sewerage, because reports of "sewerage had exploded like bombs" in some areas and there were concerns that evacuees may have been contaminated with sewerage on their skin. In addition grocery stores were selling perishable food items during the initial hours after the earthquake, when power was unavailable.

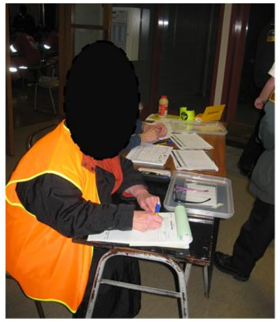
Linwood High School Emergency Centre



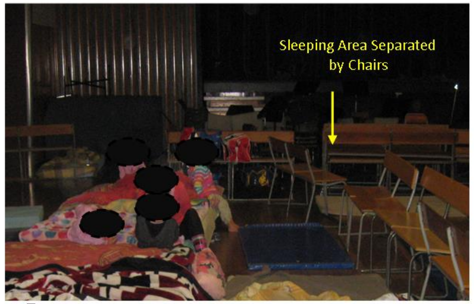
A– Linwood Emergency Centre Layout



B– Social Services and Sleeping Hall (Key-1) Floor Plan



C– Photograph of Reception (2)



D– Photograph of Sleeping Area (From Figure B)

KEY

1. Social Services and Sleeping Hall
2. Reception
3. Toilets, 3a—Portable Toilets
4. Rubbish Skip
5. Eating Area for 140 People, 5A— Kitchenette for Salvation Army Access Only, 5B— Seating Area for Dining
6. Support Section (EC Staff Only)
7. EC Staff Toilets (No Public Access)
8. Water Tanker for Public and EC Users
9. First Aid Room with Bed
10. Isolation with Attached Toilets & Kitchenette (Final Position)
11. Information Board
12. Upstairs EC Staff Room– EC Staff Access Only.

- - - - Gates— No public Access
- - - Pedestrian & EC Staff Access
- - - EC Users Walkway
- - - Monitored Public Access Gate

Figure M-1: Linwood High School Emergency Centre Layout following the September 4, 2010 earthquake.

Table M-1: Timeline of events for Linwood High School emergency centre following the September 4, 2010 earthquake. Abbreviations: EC=Emergency Centre, LEC= Linwood High School Emergency Centre, NC= No Change to previous day, PLs= Portable Lavatories.

Number of Days EC Open	Evacuees Housed (Approx.)	Main Infrastructure			Comments
		Water	Sewerage	Power	
DAY 1 4-Sep	400-500	-Building Water Supply: Not used -External drinking water tank	-Building Lavatories	Grid Power	-Large volume of evacuees -No bottled water available -Underequipped to clean EC -EC staff average 15-18 hour shifts (senior EC management staff did 24 hour shifts)
DAY 2 5-Sep	400-450	-Same services as day 1 -Bottled Water Available	-Building Lavatories -PLs arrive to cater to increased evacuees.	NC	-Cleaning: Church volunteers, professional cleaners not on site yet -Support agencies arrive after took 2-3 days to understand what type of services needed at LEC -Community resources arrive: Plunket -Spontaneous volunteers registered -Isolation set up- diarrhoea family arrive -EC staff average 12 hour shifts -Hand sanitiser supplies arrived and supply did not deplete henceforth
DAY 3 6-Sep	550-650	(NC)	NC	NC	-Cleaning: professional cleaning on site and Church Volunteers -Professional security arrive & gets established -First Diarrhoea family arrive at EC -EC staff average 12-18 hour shifts
DAY4 7-Sep	600-650	NC	NC	NC	-Services present: cleaning, support agencies, professional security: NC -Second Diarrhoea family arrive at EC -Professional psychiatric help arrives for evacuees -Staff rosters established: Staff doing 8-10 hour shifts -Clean sleeping hall - Routine established for running EC
DAY 5 8-Sep	600-650	NC	NC	NC	-Cleaning, support agencies, Professional Security: NC -Staff rosters established: Staff doing 8-10 hour shifts -Diarrhoea among few EC staff (approximately 5 staff members) -Commenced cleaning the sleeping hall as routine henceforth
DAY 6 9-Sep	600-650	NC	NC	NC	-Services present: cleaning, support agencies, professional security: NC -EC Staff Fatigue set in: Coastguard Canterbury other volunteer groups to help with EC shifts
DAY 7 10-Sep	450-500	NC	NC	NC	-Services present: cleaning, support agencies, professional security, psychiatric services: NC -Coastguard Canterbury & other volunteer groups help with EC shift rosters
DAY 8 11-Sep	400-450	NC	NC	NC	-Services present: cleaning, support agencies, professional security: NC -Coastguard Canterbury & other volunteer groups help with EC shift rosters
DAY 9 12-Sep	50-70 EC CLOSED	NC	NC	NC	-Services present: cleaning, support agencies, professional security: NC -Remaining evacuees were transferred to other ECs that were open. -CLEAN VENUE TO CLOSE

APPENDIX N: Raw Results For Burnside High School Emergency Centre

BURUNSIDE HIGH SCHOOL LAYOUT: OVERVIEW

The Burnside High School Emergency Centre's (BEC's) layout operated in a similar fashion to LEC. Instigated by security at the front entrance to BEC, all evacuees "signed-in" for information or services via reception area (Figure N-1). It was mandatory for all EC staff to sign-in at reception. From reception, two manned gates guided evacuees into the registration area as well as the specific areas where social services were housed (Figure N-1). When staff or evacuees left BEC, it was mandatory to "sign-out" at reception for the same health and safety reasons as LEC. Analogous to LEC, a Red Cross from enabled access to all services offered at BEC, especially meals. Initially BEC services were limited to the main hall with staff carrying out majority of the services (Figure N-2).

The BEC layout changed as types of social services and evacuee number increased. Initially, social services and registration was housed inside the main hall (Figure N-2). After 2-3 days, those services moved into disparate classrooms. It allowed extra space, better traffic flow, privacy, cater to increased social service staff and cultural sensitivity like specific sleeping arrangements (Figure N-1). More importantly using classroom blocks, enabled social services (with their respective staff) to set up efficiently and "free-up" BEC staff to oversight roles: rather than "doing" a job, they were micro-managing collaboratively with social services staff.

BURNSIDE HIGH SCHOOL LAYOUT: SERVICES

Services offered at BEC and timeline are outlined in Table N-1. For the first 8 hours, BEC operated on a camping generator with no grid power. Compared to CEC, installing power was more difficult at BEC due to building type. Without knowing damage to the infrastructure systems, BEC locked all lavatories and disabled water drinking fountains across the school for health and safety reasons.

The water tank, originally located inside BEC layout, got relocated to the BEC entrance upon refill, because of the growing public demand for water. In doing so, it abated unnecessary foot traffic inside the BEC. For caution, there were notices on the public information board to boil water obtained from the water tank because BEC could not verify if the water was tested.

Social services "trickled in" over the initial days BEC was open. One of the earliest social services to arrive was representatives from a travel agency. BEC received busses of visitors-tourists, conference participants and international sports teams arriving from central Emergency Centres (ECs) (Cranmer Square/Hagley). In most cases, those people did not hold any travel documents nor travel luggage because their hotels were cordoned-off due to earthquake damage. The travel agency helped displaced visitors to arrange travel documents and flight arrangements. School vans with school teachers as drivers transported visitors to the airport. BEC was initially designed to cater to airport passengers as transit venue to the airport in the event of a disaster emergency.

BURNSIDE HIGH SCHOOL LAYOUT: STAFF

BEC operated with 10-12 trained volunteer staff with spontaneous volunteers working for the trained staff. In total up to 30 staff (per shift) operated BEC. Spontaneous volunteers included host of people—professionals, school volunteers, pre-school teachers and nurses. Involving spontaneous volunteers required a trained staff member dedicated to managing rosters to confirm and request shifts. It made managing rosters often an arduous process. School pupils formed an essential component of the spontaneous volunteers' team because of their knowledge in the school and its surroundings. Among other responsibilities—such as assisting with communication systems and hand sanitiser stations—BEC school pupils efficaciously acted as runners for the trained staff: deliver hand-written notes, messages, and paper work to staff located at the opposite end of BEC.

When BEC first opened to the public, the staff shifts lasted up 18 hours because of the time taken to establish social services and staff routine. On day three, staff rosters were implemented to prevent staff fatigue. This change coincided with the BEC establishing overall routine services (Table N-1).

A–Burnside High School Emergency Centre Layout

Figure N-1: Burnside High School emergency centre layout following the February 22, 2011 earthquake. The photographs B, C, D, E, F, G, H, and I represent the various components of the emergency centre outlined in A. Abbreviations: CD=Civil Defence, EC=Emergency Centre. The photographs are courtesy of Resilient Networks.

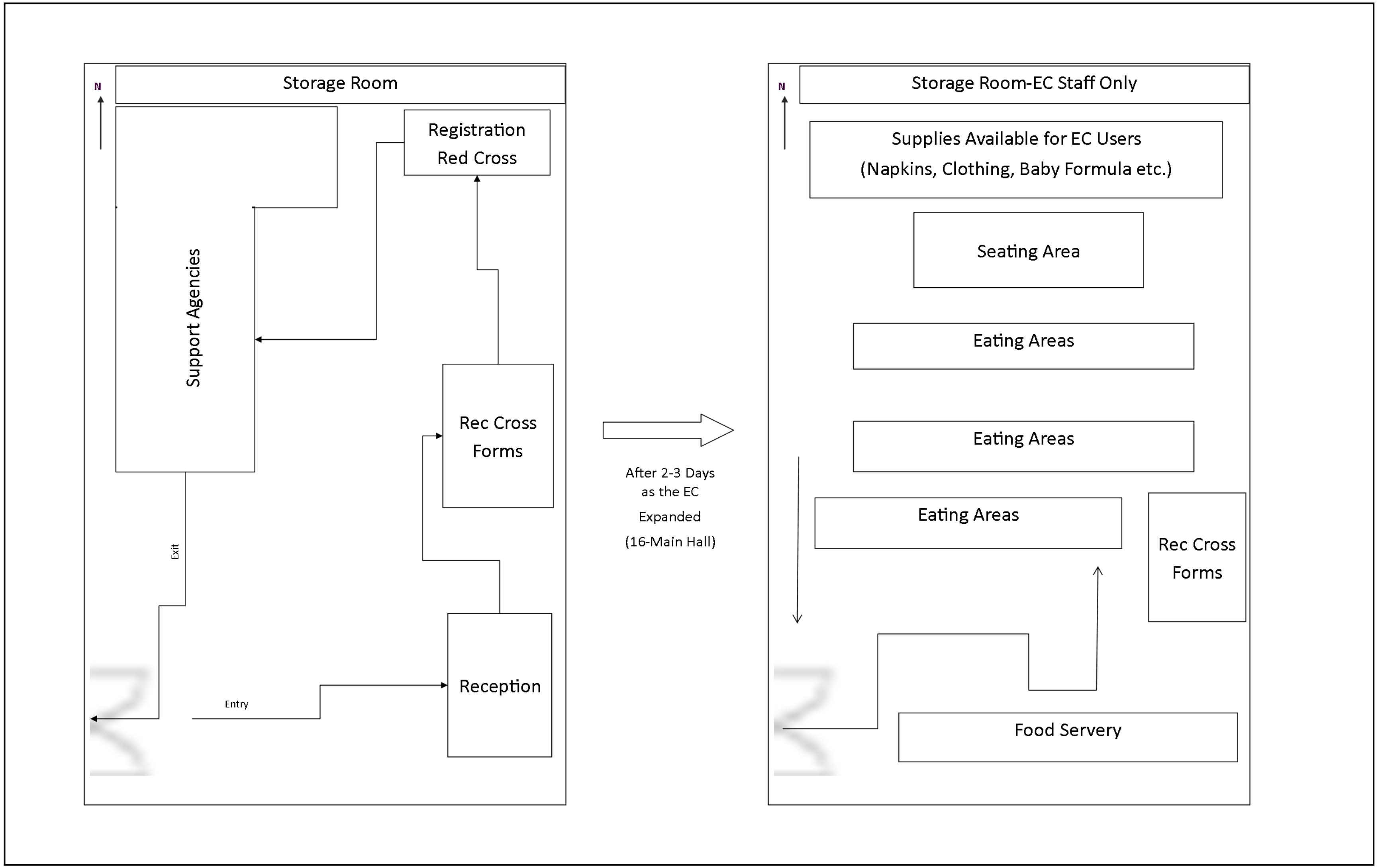


Figure N-2: Burnside High School emergency centre layout of the food hall following the February 22, 2011 earthquake.

Table N-1: Time line of events for Burnside High School emergency centre following the February 22, 2011 earthquake. Abbreviations: EC=Emergency Centre, NC= No Change to previous day, PLs= Portable Lavatories.

Days EC Open	Evacuees Present (Approx.)	Main Infrastructure			Comments
		Water	Sewerage	Power	
DAY 1 22-Feb	400	-No building water supply for 12-36 hours -Bottled water available	-Building lavatories functioning but prohibited use due to sewerage network damage - Around 20 portable lavatories arrived within 8 hours of EC opening.	-No grid power -Used a camping generator and two spotlights in the court-yard -Grid power returned by 7pm	-EC opened in the evening when emergency declared by officials (2-3 hours after the earthquake) -Tourists, arrived from Central city in busses -Mandatory hand sanitiser stations that were manned with EC staff at all times established henceforth -Commercial cleaners present -Portable lavatories arrived within 8 hours (main form of sewerage) -Sleeping arrangements using gym mats -Mandatory hand sanitisor stations established -Large volume of evacuees from -No bottled water available -Underequipped to clean EC -EC staff average 12-18 hour shifts -Lavatories cleaned twice -Portable lavatories emptied as needed -Isolation rooms used- immunosuppressant evacuee - Shut off fountains around the school to prevent evacuees" drinking water from the fountains
DAY 2 23-Feb	850	-No building water supply for 12-36 hours. -Water tagged unsuitable to drink -Bottled Water available -Water tank-Drinking water was delivered in a milk tank. Heavy public demand for water. Water had to be boiled for drinking.	-Building Lavatories -Portable Lavatories	-Grid Power	-Change EC layout for registration, reception, social services. -Professional cleaners stationed on site 24/7 henceforth, especially for lavatories because cleaning twice a day was not enough. Cleaned all EC spaces - Portable lavatories emptied as needed -Social services started to "trickle" in over the next few days. One of the first social services present was Wellington Ambulance, NZ police, travel agents. - Resources arrive- sleeping mattresses & blankets. -Spontaneous volunteers registered -Isolation set up & used: Diarrhoea family arrive -EC staff on average did 12 hour shifts -Professional Security present 24hours
DAY 3 24-Feb	No Data Available	-Water tagged unsuitable to drink -Water Tank -Bottled Water	NC	NC	-Beginning to have people body washing in the lavatories -Isolation Rooms used- Diarrhoea family (at EC for approx.3 days) - Rosters setup for EC staff to do 8 hour per shift with a hand-over meeting henceforth. A shift can be one of three time slots: 7am-3pm, 3pm-11pm, 11pm-7am. A hand-over meeting designed to last 30minutes for each shift change.
DAY4 25-Feb	No Data Available	-Water tagged unsuitable to drink -Water Tank -Bottled Water	NC	NC	- Shower Units set up and toiletries provided -Health Officials" inspection: Initial inspection took about 4- hours -Number of evacuees housed decreased compared to previous day -Cleaning roster set up within professional cleaners and PL serviced regularly, or as needed - Hand sanitiser usage was strictly enforced -EC staff roster followed
DAY 5 26-Feb	No Data Available	-Water Tank -Bottled Water	NC	NC	-Health Officials" inspection that lasted about an hour -EC services are beginning to transform into a regular routine. -Number of evacuees decreased compared to previous day. -Cleaning roster set up within professional cleaners and PL serviced regularly, or as needed - Hand sanitiser usage was strictly enforced.
DAY 6 27-Feb	No Data Available	-Water Tank -Bottled Water	NC	NC	-Health Officials" inspection, about an hour - 14 Washing Machines and 14 Driers arrive and provided with washing materials such as washing powder. The machines were guarded with security at all times -EC operation routine fully established -Number of evacuees housed decreased compared to previous day. -Cleaning roster set up within professional cleaners and PLs serviced regularly, or as needed - Hand sanitiser usage was strictly enforced -EC staff roster followed
DAY 7-10 28-Feb	No Data Available	NC	NC	NC	- EC operated by following a daily routine whilst the number of evacuees using the EC dropped sharply -Cleaning roster set up within professional cleaners and PL serviced regularly, or as needed - Hand sanitiser usage was strictly enforced -EC staff roster followed
Day 10-14 3-Mar	100- EC CLOSED				-Existing evacuees were transported to another EC that was open. -Also, evacuees were asked if any further helped or resources was needed to help evacuees resettle

APPENDIX O: Emergency Centre Raw Results for Cowles Stadium Emergency Centre

COWLES STADIUM LAYOUT: LAYOUT OVERVIEW AND SERVICES

The CEC layout was depicted by the building type; a sports stadium. The core facilities were housed inside the capacious sports stadium. The stadium was separated into disparate sections and walkways using chairs and bleachers (Figure O-2). Some sections had multi-functions for efficient use of space. For example, social service area by day; men's sleeping area by night.

The first "meet and greet" upon entering CEC was reception located in the main foyer of the sports stadium (Figure O-2). Evacuees were then forwarded to registration using a single thoroughfare into the sports stadium main hall (Figure O-2). Reception and registration functions remained same as LEC and BEC. Once a completed Red Cross form was obtained which outlined required services—evacuees were free to use services housed inside the sports stadium hall. Like LEC and BEC, evacuees and staff had to "sign-in" and "sign-out" every time leaving or entering the CEC.

EC services were inconveniently hindered by liquefaction damage around the back of the sports stadium that delimited road access to ambulances (Figure O-1). An ambulance "got stuck" at the main entrance of the triage area in one instance. Unique to CEC, the EC layout included a triage area that was separated by bleachers and chairs in the main sports stadium (Figure O-2). The self-contained triage area had its own lavatories, isolation rooms, staff room for health professionals; and private entrance for ambulance staff (Figure O-1). The setup was open 24 hours that enabled registered evacuees to enter the triage area voluntarily to be seen by a doctor.

COWLES STADIUM LAYOUT: INFRASTRUCTURE

When CEC opened, it had no grid power, neither running water nor building sewerage facilities. However, alternate facilities were implemented within hours. Power was connected via a diesel generator because of the sports stadium grid layout, an hour after CEC had opened. Water was restored utilising 10,000-15,000L water tanker that was installed after the September 4, 2010 earthquake. In addition, a drinking water tank was stationed on the main street which, allowed public access to water whilst bottled water was reserved for CEC users (evacuees and staff). Eight PLs, from various commercial companies delivered to accommodate sewerage facilities on the first day; with another eight delivered the next day.

Initially, there was an issue with emptying filled PLs: only the PLs belonging to the respective companies were being emptied. This meant some PLs were emptied whilst the rest stayed full and unable to use. It was rectified promptly, given a “state of emergency” was declared across the city.

Many participants had felt the PLs were being filled faster than they were emptied. In one instance, a staff member “physically emptied” a PL in order to prevent overflowing: a duty that was “over and beyond the call” of volunteer duty. It showed assiduous staff effort to operate CEC: do what was needed to be done.

Building lavatories were locked to stop evacuees from using them because of the damaged sewerage network in the CEC ward. Yet, on the last day CEC was open, a building lavatory, had what appeared to be diarrhoea. Because of this reason couple with the progressive demand for PL usage, health officials asserted to close CEC that afternoon.

COWLES STADIUM LAYOUT: STAFF

Operating CEC required 26-30 staff that included volunteers from Coastguard Canterbury. Like LEC and BEC, the staff shifts lasted 10-12 hours initially during CEC setup but reduced to 8 hour shifts the next day, with a hand-over meeting at the beginning and end of each shift. Staff required reading a health and safety form at the beginning of each shift; a lesson learnt from operating LEC to introduce a health and safety form for staff. The health and safety form consisted of the following information: sign in or sign out, chain of command, evacuation area, earthquake procedure, ambulance, suitable clothing, food handling and consumption; drinking water, regular breaks, lavatories, general hygiene; and briefings. Upper management ensured staff members were taking regular breaks. In addition, spontaneous volunteers’ names were collected but delimited its use because they could be vetted for their neither qualifications nor background check.

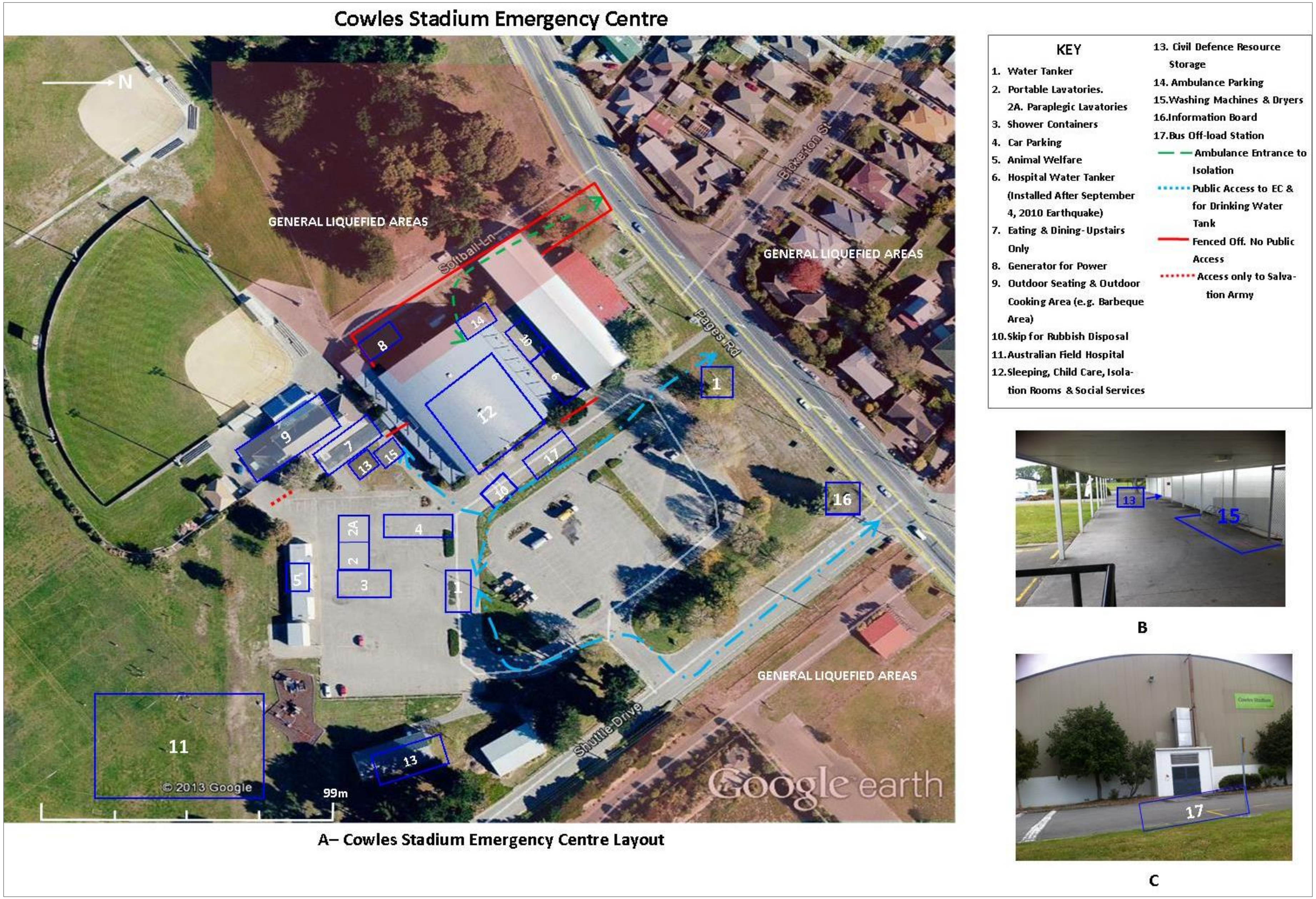


Figure O-1: Cowles Stadium emergency centre layout following the February 22, 2011 earthquake. Abbreviation EC= Emergency Centre.

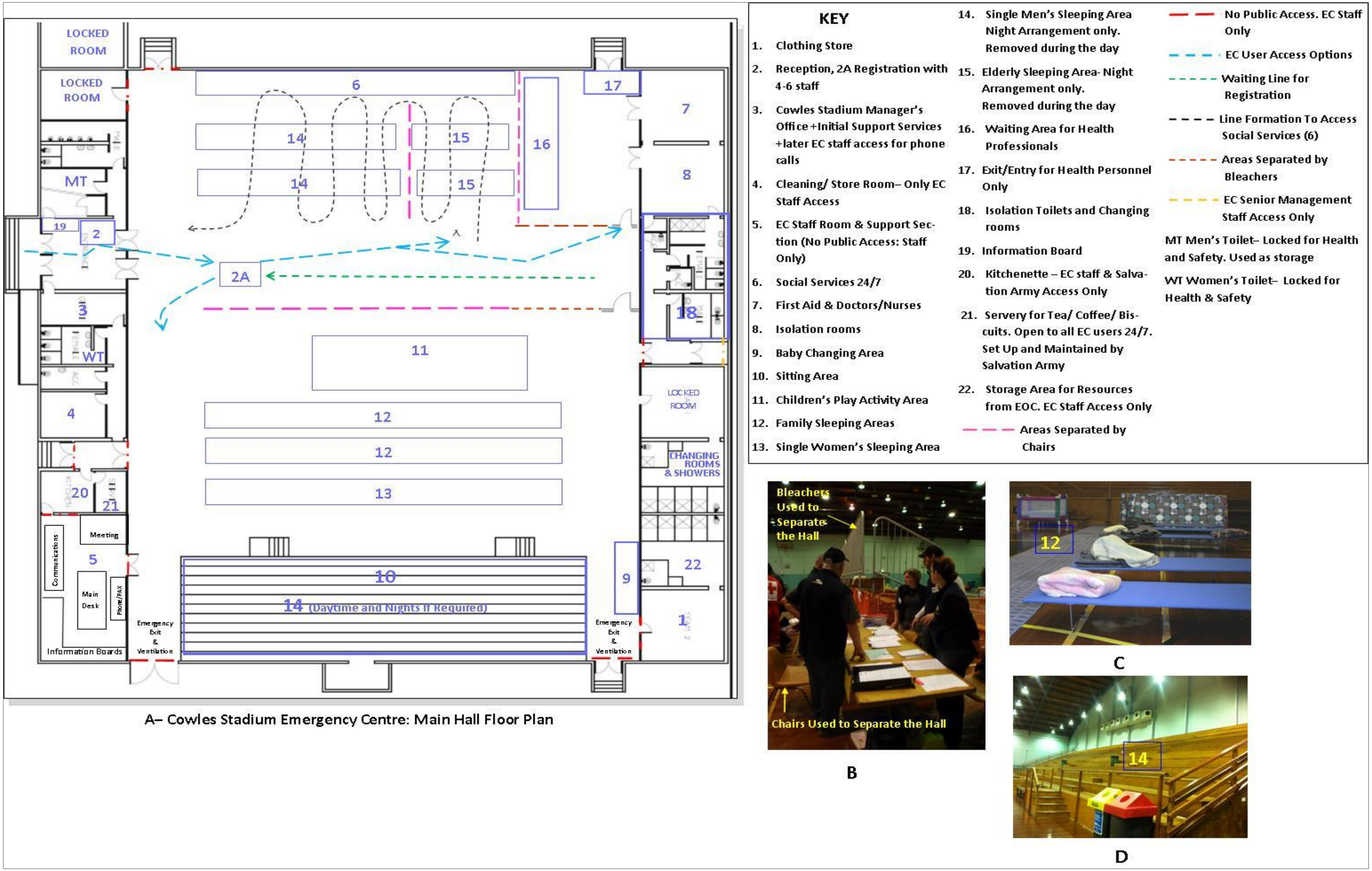


Figure O-2: Cowles Stadium emergency centre. The main hall layout following the February 22, 2011 earthquake. Abbreviations: EC= Emergency Centre, EOC= Emergency Operations Centre.

Table O-1: Time line of events for Cowles Stadium emergency centre following the February 22, 2011 earthquake. Abbreviations: EC=Emergency Centre, NC= No Change to previous day, PLs= Portable Lavatories.

Days EC Open	Evacuees Present (Approx.)	Main Infrastructure			Comments
		Water	Sewerage	Power	
DAY 1 23-Feb	250-300	-No building water supply: Bottled Water available -10 to 15000L installed water tank but took some time to establish as some connecting pipes were stolen before the February 22, 2011 earthquake	-Building lavatories functioned but had no water amid damaged sewerage network- Prohibited use - 8 PLs arrived	-No grid power -Diesel Genera-tor at the back of the truck for continuous supply: full power by 7pm	-EC opened in evening(around 6pm) -Heavy public demand for water -Professional cleaners 2-3 times per day -Resources arrive: community help, blankets, and donated goods -Support agencies including security, St John ambulance, arrived and stationed for 24 hours with rotating shifts for respective staff -Some PL companies emptied PLs belonging to their company only: especially not competitors. This was rectified immediately -Despite prohibited lavatory use, the lavatories were used by evacuees: put locks on lavatories - PLs placed in car park because easier to empty -Mandatory hand sanitiser stations emplaced and manned by CD staff henceforth -10-12 hour shifts
DAY 2 24-Feb	250-300	- No building water supply -Bottled Water available -10 to 15000L installed Water Tank	No functioning building lavatories - Another 8 PL arrived -16 PLs total -1 lavatory per 18 people	-Grid Power	-Professional cleaners stationed on site 24/7 henceforth. Cleaned all areas of the EC. The lavatories were cleaned about every 3 hours - PLs full and could not empty at the rate they were being filled. Hence, had to restrict PL use that were already full capacity -Spontaneous volunteers registered -Isolation set up- Diarrhoea family arrive -EC staff on duty did 8 hour shifts on roster basis -Mandatory hand sanitiser usage to everyone intensified -Entertainment and childcare area established
DAY 3 25-Feb	350-400 -Due to health concerns EC was closed by EC staff in the evening	-No building water supply -Bottled Water available -Installed Water Tank 10-15000L	NC	-Grid Power	- Intense cleaning continued and intensified such as cleaning the sleeping hall -By the afternoon, most PLs were full and could not be emptied at the rate being filled. - Afternoon stomach pains, fever, diarrhoea and vomiting were observed - A person had broken into the locked building lavatories where diarrhoea was found -Health officials evaluated the situation in the afternoon and ordered to close the EC on public health grounds -Evacuees were told the EC was closing down due to health concerns and offered services from another EC. - 78 evacuees were transported to another EC - Laundry and 3 shower blocks (with 6 showers in each block), was put in place at Cowles Stadium for the community, after the EC had closed (about 2-3 weeks)

APPENDIX P: Core Services Provided by the Emergency Centres

Table P-1: Reception service (part of the Core services) provided at three emergency centres following the February 22, 2011 earthquake.

Descriptive Components of an Emergency Centre		Emergency Centre (EC)		
Component Name	**Component Description**	**Linwood High School EC (LEC)**	**Burnside High School EC (BEC)**	**Cowles Stadium EC (CEC)**
1) Reception	• First-port-of-call for incoming evacuees. Reception EC staff assess necessities, issues or special needs. Special needs could have been elderly, infectious diseases, stress, language barriers, cultural sensitivities, and medical status. • All evacuees and staff must sign a form each time to enter/leave an EC. Reception acts to filter services that are needed by the evacuees before entering the EC. • Reception has at least two Civil Defence (CD) staff. Depending on the site, reception is located at the gate or a conspicuous area with open access. • Reception would also be equipped with a telephone message pad, EC checklist and a volunteer form.	• Reception was located inside the building foyer with 2 CD staff. • Security ensured all entering LEC was guided into reception.	• Reception had an atlas (using the school resources) to identify people with different languages. • A 3-car garage within the school premises was used as a reception area. Hence, reception area was sheltered and located at the very entrance into the BEC. • The entrance was manned with professional security guards to guide evacuees into the EC via reception. • There were minimum 2 CD personnel present at reception at all times.	• Reception was located at the opened entrance to the CEC. So all incoming and outgoing evacuees must use this entrance to sign in and sign out. • At least 2 CD staff attended Reception.

Table P-2: Registration service (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

<table>
<tr><th colspan="2">Descriptive Components of an Emergency Centre</th><th colspan="3">Emergency Centre (EC)</th></tr>
<tr><th>Component Name</th><th>Component Description</th><th>Linwood High School EC (LEC)</th><th>Burnside High School EC (BEC)</th><th>Cowles Stadium EC (CEC)</th></tr>
<tr><td rowspan="2">2) Registration</td><td rowspan="2">• If evacuees required EC services (other than publicly available resources), a registration form, called Red Cross from, was filled. This enabled to trace individuals, reunite families, and provide assistance.
• Red Cross From enacted as “permission slip” to get access to various parts of the EC.</td><td colspan="3">• Had to have a Red Cross From to get pass gates staffed with CD personnel such as into social services and food service. Registration was open 24 hours.</td></tr>
<tr><td>• Registration was placed inside the sleeping hall</td><td>• Initially, CD staff manned Registration desk for a single night and then replaced by Red Cross staff.</td><td>• Registration was conspicuously placed at the entrance of the sleeping hall.</td></tr>
</table>

Table P-3: Social and emergency centre services (part of the Core services) provided at three emergency centres following the February 22, 2011 earthquake.

Descriptive Components of an Emergency Centre		Emergency Centre (EC)		
Component Name	**Component Description**	**Linwood High School EC (LEC)**	**Burnside High School EC (BEC)**	**Cowles Stadium EC (CEC)**
3) Social Services & Emergency Centre services	• Both government and non-government co-ordinated and provided on-site social services. • Selection of services is shown below from EMTC. 1. Child Youth & Family- Family concerns 2. Citizens Advice Bureau – General Advice 3. Canterbury District Health Board (CDHB)- Community Health 4. Housing New Zealand – accommodation 5. Plunket-Child and Family Health 6. Red Cross-Support/registration 7. Royal New Zealand Society for the Prevention of Cruelty to Animals (RSPCA)-Animal Welfare 8. Salvation Army-(Counselling/ food distribution/ clothing/ bedding) 9. St John Ambulance 10. Work & Income New Zealand- Financial Support 11. Victim Support-Emotional Support	Social Services present: 1-6, 8-11 Additional Services: • Linwood College Principal • Professional Security Companies-Armourguard/ADT Security, Red Badge, Red Guard. • NZ Police • NZ Defence Force • Professional Cleaning Company-Spotless Cleaning Company, ICT • Insurance (ACC) • NZ Police • Department of Corrections • Christchurch City Council events team-entertainment • District Nurse • Parliament Services • Commercial Catering-Continental Catering • Deaf and Blind Supports Service • Christchurch Dog Shelter at Bromley • Physiatrist • Bi Polar Support Group • Christchurch dog shelter at Bromley.	Social Services present: 1-6, 8,10-11 Additional Services: • Burnside High School Caretaker • CDHB Public health inspectors • Wellington Ambulance on Site 24/7 • NZ Police • NZ Defence Force • Professional Cleaning Company 24/7-Spotless Cleaning • Health Nurses • Volunteer CD staff that acted as language interpreters. • Tentative travel agency personnel to arrange flights & travel documents for tourists and visitors.	Social Services present: 1-6, 8-11 Additional Services: • Cowles Stadium Site Manager • Australian Field Hospital Medical Team • Insurance-ACC • Professional Security • NZ Police • Department of Corrections • NZ Defence Force • Professional Cleaning Company-24/7 - ICT • CCC events team for entertainment • General Practitioner (GPs) Doctors • Christchurch Dog shelter at Bromley

Table P-4: Accommodation service (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

<table>
<tr><th colspan="2">Descriptive Components of an Emergency Centre</th><th colspan="3">Emergency Centre (EC)</th></tr>
<tr><th>Component Name</th><th>Component Description</th><th>Linwood High School EC (LEC)</th><th>Burnside High School EC (BEC)</th><th>Cowles Stadium EC (CEC)</th></tr>
<tr><td rowspan="3">4) Accommodation</td><td rowspan="2">• Emergency and temporary accommodation provided in a safe area.
• Emergency denoted by CD manual is overnight or up to three nights maximum.
• EC accommodation layout was depicted by family groups, personal needs, age and culture.</td><td colspan="3">Gyms were used as sleeping areas, and evacuees were encouraged to be outside the sleeping areas during the day.</td></tr>
<tr><td>• Provided mattresses, blankets and pillows from Salvation Army. Used cupboard space within sleeping area to store sleeping material during the day. Used school gymnasium as the sleeping area.</td><td>• Used gym mats initially then upgraded to mattresses bought by Salvation Army the next day. Used school gymnasium as the sleeping area.
• No food was allowed inside the sleeping areas.</td><td>• Used bleachers and chairs to separate social services area into men's sleeping area at night. Used the stage area as sleeping areas.</td></tr>
<tr><td>Providing clothing items was not mandatory. However, ECs made available donated clothing to evacuees.</td><td colspan="3">• Clothing was available to evacuees, which were donated from Salvation Army. Clothing items included extra blankets and coats. However, it was noted that EC could not verify the quality of the clothing.
• LEC denied some clothing items donated from the public due to hygiene reasons.</td></tr>
</table>

Table P-5: Catering service (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

Descriptive Components of an Emergency Centre		Emergency Centre (EC)		
Component Name	**Component Description**	**Linwood High School EC (LEC)**	**Burnside High School EC (BEC)**	**Cowles Stadium EC (CEC)**
5) Catering	Evacuees and staff members were provided with food and refreshments	• Breakfast, lunch and dinner were provided at the EC. In addition, tea/coffee with snacks was available 24 hours. • Food prepared and delivered by commercial caterers. Food was distributed at the EC by Salvation Army staff. Only Salvation Army staff handled food and accessed servery area. Catering was provided for support section staff as well. • To access food service facilities evacuees had to have a completed Red Cross form. • Using hand sanitisers located throughout the food area was mandatory. • Meal times were approximately as follows: ○ Breakfast: from 8.30am-11am ○ Lunch: 12-2pm ○ Dinner: 4.30pm-6pm ○ Sometimes afternoon tea was given • There was tea/coffee available 24/7. • Hot perishable food was not available other than meal times—uneaten hot food was taken off the premises or disposed of immediately after meal times. • Meals were available to EC staff and volunteers as part of their shift. • Any rubbish was removed at the end of each meal using the building skits.		

Table P-6: Security service (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

<table>
<tr><th colspan="2">Descriptive Components of an Emergency Centre</th><th colspan="3">Emergency Centre (EC)</th></tr>
<tr><th>Component Name</th><th>Component Description</th><th>Linwood High School EC
(LEC)</th><th>Burnside High School EC
(BEC)</th><th>Cowles Stadium EC
(CEC)</th></tr>
<tr><td rowspan="3">6) Security</td><td rowspan="3">• Maintain safety to EC dwellers by monitoring restricted access, managing traffic flow and meeting visitors.</td><td rowspan="2">• Initially CD staff provided security then sought professional security personnel. Henceforth professional security & NZ Police were present 24/7 at the EC.</td><td colspan="2">• Professional Security was present on the second day. NZ Police continually present from evening to following day morning, and intermittently present throughout the day.
• Children play areas were observed by NZ police for suspicious behaviour.</td></tr>
<tr><td>• Two security personnel in the sleeping area at night- a male professional security personal and a woman from EC staff (to attend to young children).
• Security supervised cordoned areas
• BEC had members of the public impersonating EC staff by wearing high visibility vests. Security attended to those issues.</td><td>• Police would come in with their documentation for people of interest.</td></tr>
<tr><td colspan="3">• NZ police being present provided additional security, especially at night. NZ police also kept watch for sexual offenders and any misconduct in behaviour. Having professional security coupled with NZ police provided a sense of “presence” to both the evacuees and the staff.
• NZ Police was stationed at night.
• Security guards conducted routine walks around the EC to check unused areas were not occupied by the public.
• Security curbed people that were coming into the EC just to use the free service.
• Security representative attended the EC debrief meeting at the end of each shift.</td></tr>
</table>

Table P-7: Animal Welfare (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

Descriptive Components of an Emergency Centre		Emergency Centre (EC)		
Component Name	**Component Description**	**Linwood High School EC (LEC)**	**Burnside High School EC (BEC)**	**Cowles Stadium EC (CEC)**
7) Animal Welfare	• Animal welfare shelter was established at EC vicinity to aid owners to provide basic welfare needs for their animals. Basic welfare needs include water, food, shelter and medical care. Owner remained responsible for their pets.	• Guide dog for the blind came into the LEC. The dog was allowed to enter LEC because it was classed as a companion animal. • A companion animal was considered if the animal provides medical related, psychological support or physical disability.	• Animal shelter was fenced area set up with shelter • 6-7 crates for animals. • Had issues where the owner did not want to be separated from the owner. • Only companion animals were allowed to enter buildings but BEC did not receive any such requests.	• Animals were left in the owners' cars. Most evacuees opted to keep their pets in the car overnight. • Only companion animals were allowed to enter the buildings within the LEC • Animal Control was doing rounds for all the ECs. They would come around register animals and look after them off site until reunited with owner.

Table P-8: Public information board (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

<table>
<tr><th colspan="2">Descriptive Components of an Emergency Centre</th><th colspan="3">Emergency Centre (EC)</th></tr>
<tr><th>Component Name</th><th>Component Description</th><th>Linwood High School EC (LEC)</th><th>Burnside High School EC (BEC)</th><th>Cowles Stadium EC (CEC)</th></tr>
<tr><td rowspan="2">8) Public Information Boards</td><td rowspan="2">• To supply applicable local information to the public and for evacuees.
• Some of the material written on Information Board (IB) as they come to light.
• Information included places to find petrol, food, roading, water treatment, WINZ, weather, accommodation, medical, phone numbers, utilities, situation update.</td><td colspan="3">• An outside board with information available for the public located at EC entry.
• CD staff had an information board for strictly for EC staff only.
• Information boards were updated to match routine reports to the Emergency Operation Centre (EOC).</td></tr>
<tr><td>• Public IB1-Main Road entry into EC
• Inside IB2 – Reception
• Staff only IB3-information on things that need to be done, shift changes and any additional notes
• IBs updated every two hours to coincide with sit reports (reports sent to Emergency Services Centre [EOC]) or as needed.</td><td>• Public IB1-entry gates at Reception
• Inside IB2 –Gates to social services
• Additional information available to registered evacuees such as meal times and crèche times.
• Staff only IB3-information on things that need to be done, shift changes and any additional notes.
• IB4- Eating Area IBs updated every two hours to coincide with EOC sit reports or as needed.</td><td>• Public IB1-Main Road entry into EC
• Inside IB2 - Reception
• Staff only IB3-information on things that need to be done, shift changes and any additional notes
• IBs updated every two hours to coincide with EOC sit reports or as needed.</td></tr>
</table>

Table P-9: Entertainment (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

Descriptive Components of an Emergency Centre		Emergency Centre (EC)		
Component Name	**Component Description**	**Linwood High School EC (LEC)**	**Burnside High School EC (BEC)**	**Cowles Stadium EC (CEC)**
9) Entertainment	• Entertainment to reduce tension and boredom for the evacuees, especially children.	• TV DVD area children. • Adults helped to fold cloths donated by Salvation Army. • Used members of the public to man the door for hand sanitiser stations.	• Set up classroom for Crèche with two pre-school teachers. • Art Room • Youth instructor ran games • Dave Dobbin played music • Army Band Played music • Bouncy Castle by a Church Group. • Encourage evacuees to go outside and socialise rather than sitting on a mattress.	• Sports equipment taken out of the sports hall for children to play outside. • Dave Dobbin Came to play music. DVD"s playing for the kids. • Children's play area with security being present. • Non-Governmental Organisations (NGO) & Churches come and run children's programs.

Table P-10: Volunteer co-ordination (part of the core services) provided at the three emergency centres following the February 22, 2011 earthquake.

Descriptive Components of an Emergency Centre		Emergency Centre (EC)		
Component Name	**Component Description**	**Linwood High School EC (LEC)**	**Burnside High School EC (BEC)**	**Cowles Stadium EC (CEC)**
10) Volunteer Co-ordination	• Co-ordinate trained and spontaneous volunteers at an EC. They can be any member of the public.	• Spontaneous volunteers log sheet was taken, but not used as you could not have "vetted" them 2-3 days after. • Feed Back to council • 250 spontaneous volunteers logged.	• Large volume of Spontaneous volunteers recorded. • From all different backgrounds. In a rostered setting became unreliable. Could not do back ground checks to verify qualifications. • Nurses came off shift to help. • Asking spontaneous volunteers to help out on shifts. Spontaneous volunteers working for the trained volunteers. • Burnside High School pupils as runners and carry out small errands. They were good because they knew the building.	The community effect. Group of volunteers came before CEC had opened to the public to help and delivered water tanks.